CFTRI-MYSORE
1601
Cheese.

Page No te of

# CHEESE

# CHEESE

A Treatise on the Manufacture of American Cheddar Cheese and Some Other Varieties—Intended as a Text-Book for the Use of Dairy Teachers and Students in Classroom and Workroom—Prepared Also as a Handbook and Work of Reference for the Daily Use of Practical Cheese-Makers in Cheese Factory Operations.

By
LUCIUS L. VAN SLYKE, Ph.D.
*The Late Chief Research Chemist of the New York Agricultural Experiment Station and Professor of Dairy Chemistry in the New York State College of Agriculture at Cornell Uuiversity.*

WALTER V. PRICE, Ph.D.
*Professor of Dairy Industry,*
*University of Wisconsin.*

*Illustrated*

REVISED AND ENLARGED

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE * MYSORE. *
5 OCT 1951
LIBRARY

New York
ORANGE JUDD PUBLISHING COMPANY, Inc.
1949

1601

COPYRIGHT, 1927, 1932, 1938, 1949 BY
ORANGE JUDD PUBLISHING COMPANY, INC.

PRINTED IN THE UNITED STATES OF AMERICA

*This book or any part thereof may not be reproduced without permission of the publishers, except by a reviewer who wishes to quote brief passages in connection with a review for inclusion in a magazine or newspaper.*

F8, 3M
N27; 49

CFTRI-MYSORE
1601
Cheese.

# PREFACE

## To First Edition

The *practice* of cheese making embraces a systematic series of mechanical operations, which have been gradually developed by experience and observation. In its widest application, it includes (1) the production and care of milk; (2) the conversion of milk into cheese; and (3) the care of the manufactured product until it is ready to be used as food.

The *science* of cheese making includes a systematic arrangement of facts and principles which explain the practices of the industry. It embraces (1) a knowledge of the constituents of milk and the relation of each to the manufacturing operations and to the characteristics of the finished product; and (2) a knowledge of the principles which govern the chemical, biological and physical changes which occur during the manufacture, curing and marketing of cheese.

While cheese has been made thousands of years, the growth of accurate, systematic knowledge regarding its manufacture has taken place chiefly during the past 50 years. Newly developed technique in bacteriology, chemistry and physics affords new methods of attacking unsolved problems and serves to emphasize the meagerness of our present knowledge as well as to stimulate further inquiries.

The main portion of this book is devoted to Cheddar cheese because it is the kind most extensively made in America, and also because this variety serves to illustrate so many of the principles which underly the manufacture of all varieties of cheese. The growing economic importance of soft unripened cheese and of processed cheese has encouraged the assembling in this book of new information along these lines.

It is not expected that any book, however complete and clear, will enable one to make cheese successfully without the help of a competent teacher. It is hoped that the specific directions for some of the manufacturing operations will be as useful to the beginners as the careful discussions and the extensive list of references should be to the advanced students.

It is with a sense of obligation and appreciation that we express our thanks to those commercial and educational institutions which have contributed numerous views of equipment, buildings, and the like, to the improvement of this book.

*University of Wisconsin*
*Madison, Wisconsin*
*September, 1938*

# PREFACE

## To Second Edition

Dr. Lucius Lincoln Van Slyke died at Geneva, New York, on September 30, 1931, in his seventy-third year.

In the field of dairy chemistry, Dr. Van Slyke was an outstanding scholar for nearly four decades. He made numerous contributions to scientific literature. Many of his studies were directly concerned with the problems of the practical cheese maker. The results of his researches provided fundamental information for scientists, technicians, and artisans.

It is entirely fitting that his name should continue to identify his contributions to the development and the material content of this text.

The second edition of "Cheese" covers the same general subjects as the first edition. Some sections have been expanded and others contracted. Changes in the cheese industry and the accumulation of technical information have determined the trend of the revisions.

This edition again attempts to answer questions that are frequently raised by students and by men in industry. The discussions are intended to be as practical and non-technical as it is possible to make them.

The valuable suggestions and criticisms of Dr. H. E. Calbert and Dr. William C. Winder of the University of Wisconsin, who reviewed certain sections of this manuscript, are gratefully acknowledged. The reader should understand that the errors which he may discover in this edition are in those sections which my friends did *not* review.

Walter V. Price

*University of Wisconsin*
*Madison, Wisconsin.*

# CONTENTS

CHAPTER PAGE

1. THE CONSTITUENTS OF MILK . . . . . . . . . 1

2. VARIATIONS IN THE PROPORTIONS OF CONSTITUENTS OF MILK . . . . . . . . . . . . . . . . 19

3. THE COMPOSITION AND QUALITY OF CHEDDAR CHEESE 31

4. STANDARDIZATION OF MILK FOR CHEESE . . . . . 40

5. MILK CONSTITUENTS AND THE YIELD OF CHEESE . . . 55

6. METHODS OF PAYING FOR MILK FOR CHEESE MAKING . 68

7. MICROORGANISMS AND CHEESE MAKING . . . . . . 79

8. THE QUALITY OF MILK FOR CHEESE MAKING . . . 94

9. STARTER . . . . . . . . . . . . . . . . 117

10. ESSENTIALS OF CHEESE MAKING . . . . . . . . 138

11. CHEDDAR CHEESE MAKING: PRELIMINARY STEPS . . . 153

12. CHEDDAR CHEESE MAKING: CUTTING TO MILLING . . 165

13. CHEDDAR CHEESE MAKING: SALTING TO SHIPMENT . . 186

14. MODIFICATIONS OF THE CHEDDAR PROCESS . . . . . 202

15. DEFECTS IN CHEDDAR CHEESE: MOISTURE, ACIDITY, AND FLAVOR . . . . . . . . . . . . . . . 219

16. DEFECTS IN CHEDDAR CHEESE: BODY AND TEXTURE . 239

17. DEFECTS IN CHEDDAR CHEESE: COLOR AND FINISH . . 254

18. JUDGING AND DESCRIBING THE ATTRIBUTES OF CHEDDAR CHEESE . . . . . . . . . . . . . . . . 266

19. TECHNOLOGY OF CHEDDAR CHEESE RIPENING: CURING TREATMENTS . . . . . . . . . . . . . . 289

CHAPTER PAGE
20. Technology of Cheddar Cheese Ripening: Losses of Weight . . . 304
21. Changes during the Ripening of Cheddar Cheese . 318
22. Packaging Cheddar Cheese . . . 335
23. Process Cheese . . . 355
24. Cottage Cheese . . . 382
25. Cream and Neufchatel Cheese . . . 406
26. Whey and its Utilization . . . 431
27. The Cheese Factory . . . 445
28. Analytical Methods . . . 456
Index . . . 501

## CHAPTER 1

# THE CONSTITUENTS OF MILK

It is desirable to consider briefly the nature and characteristics of the chief constituents of normal milk in order to explain what happens to them and how they function in the making and curing of cheese.

### NORMAL MILK

Normal milk of cows is the whole, fresh lacteal secretion obtained by the complete milking of one or more healthy cows, excluding that obtained within 15 days before and 5 days after calving, or such longer period as may be necessary to render the milk practically colostrum-free; it contains not less than 8% of milk-solids-not-fat, and not less than 3¼% of milk fat. This is the definition of the Milk Ordinance and Code of the U.S. Public Health Service (1939).

### MILK CONSTITUENTS

Normal milk of cows contains certain compounds and classes of compounds. Some are present in large proportions, others are there in only trace amounts. A list of these constituents is presented in table 1:1. They have different values in cheese making. Some are absolutely essential, while others function in an obscure manner, if at all.

### WATER

Approximately 87% of cow's milk is water. Most of it is "free" water which can be easily separated from the other milk constituents. Some of it is intimately associated as water of hydration with some of the other milk components, particularly the proteins. The other milk constituents are either dissolved or suspended in the water phase.

During the curd-making process some of the original water content of milk is removed in the form of whey. A proportional

TABLE 1:1. CONSTITUENTS OF MILK

(1) **Water**
(2) **Fats**
    a. true fats
    b. fat-like substances
(3) **Proteins**
    a. casein
    b. lactalbumin
    c. lactoglobulin
(4) **Lactose**
(5) **Salts**
  Metallic elements
    a. calcium
    b. magnesium
    c. potassium
    d. sodium
  Non-metallic elements
    a. chlorides
    b. citrates
    c. phosphates
  Traces of others
(6) **Pigments**
    a. carotene
    b. riboflavin
    c. xanthophylls
(7) **Vitamins**
    a. vitamin A
    b. thiamin
    c. riboflavin
    d. nicotinic acid
    e. pantothenic acid
    f. pyridoxine
    g. ascorbic acid
    h. vitamin D
    i. vitamin E
    j. vitamin K
    k. "grass juice factor"
(8) **Enzymes**
    a. protease
    b. lipase
    c. catalase
    d. peroxidase
    e. phosphatase
    f. reductase
  Traces of others
(9) **Gases**
    a. carbon dioxide
    b. nitrogen
    c. oxygen

amount of the soluble milk constituents of course are removed at the same time.

**Functions of water.** The water remaining in the curd and cheese performs important functions: (1) It furnishes suitable conditions for the chemical and biological reactions upon which cheese making is based. (2) It provides the moisture which is essential for the growth and activities of microorganisms. (3) The amount of water in the cheese has a direct influence upon the flavor, body, texture, color, and appearance of the finished product.

The *flavor* of the cheese is affected by the water content. The water retains milk salts, which affect flavor directly. The lactose, which is also dissolved in the water, is converted by microorganisms into other compounds which contribute to the flavor of the cheese.

The *body* or consistency of the cheese can be made firm by removing moisture, or it can be made soft by retaining moisture.

The *texture*, or extent of openings in cheese, is affected by moisture; some varieties may show increased numbers of openings or larger openings with increasing moisture, others, fewer holes. The extent of the effects depends upon the process of making and the types of microorganisms involved.

The natural *color* of cheese is usually lighter when larger proportions of water are retained in it. There are exceptions. Sometimes larger amounts of water encourage changes in color by chemical or biological agents. Excessive moisture content causes such high acidity in cheese that the proteins actually appear lighter in color and the vegetable dye used for coloring cheese is bleached or "acid-cut."

The *appearance* of cheese may reveal excessive or deficient water content by its shape, surface structure, surface moisture, or the appearance of the cut surfaces. All of these effects of water will be considered in some detail in discussion of the making and the judging of cheese.

## MILK FAT

**Identity of milk fat.** True milk fat is a variable mixture of glycerides. These glycerides are combinations of glycerol and certain fatty acids. The glycerol molecule has three possible points of linkage in its structure where the fatty acid molecules can be attached. Molecules of a fatty acid may be attached to any one of these points, or to any two, or to all three. There are usually about ten fatty acids in milk fat. Some combination of from one to three of these acids will be found with every glycerol molecule. Such combinations are called mixed glycer-

TABLE 1:2. FATTY ACIDS IN TWENTY-ONE SAMPLES OF BUTTER-FAT FROM MASSACHUSETTS COWS FED NORMAL RATIONS
(Holland, et al., 1923)

| *Fatty acids* | *Average* | *Range* |
|---|---|---|
| | % | % |
| Soluble acids:— | | |
| Butyric | 2.932 | 2.241 to 4.230 |
| Caproic | 1.898 | 1.290 to 2.400 |
| Caprylic | 0.786 | 0.527 to 1.041 |
| Capric | 1.570 | 1.187 to 2.008 |
| Total soluble acids | 7.186 | 6.470 to 8.601 |
| Insoluble acids:— | | |
| Lauric | 5.849 | 4.533 to 7.687 |
| Myristic | 19.784 | 15.554 to 22.618 |
| Palmitic | 15.167 | 5.782 to 22.863 |
| Stearic | 14.907 | 7.803 to 20.370 |
| Oleic | 31.895 | 25.273 to 40.313 |
| Total insoluble acids | 87.602 | 86.145 to 88.471 |
| Total fatty acids | 94.788 | 94.746 to 94.980 |

ides and there are several hundred of such combinations possible in milk fat. Variations in the mixtures of glycerides may be apparent in the consistency of the milk fat. Soft fat tends to contain larger proportions of oleic acid than harder milk fat. The presence of relatively large amounts of volatile, soluble fatty acids in the mixed glycerides serves to distinguish it from the other fats. Holland et al. (1923) measured the amounts of the soluble and insoluble fatty acids in the milk of cows on normal rations; the data are shown in table 1:2.

**Physical state of fat.** Milk fat exists in milk in small globules dispersed in the liquid. Around each fat globule is a film or "membrane" of one or more adsorbed materials, the nature and identity of which have not been conclusively established. Palmer and Wiese (1933) decided that the material most closely adsorbed on the fat globule "membrane" was composed of a mixture of proteins and phospholipides.

**Size of fat globules.** Milk fat globules vary in size with such conditions as the breed, stage of lactation, health, and individuality of the cow. The numbers of globules are about the same in milks of different breeds. Freezing and unusual agitation will alter globule size. Campbell (1932) reported that 65 to 80% of the globules in Guernsey milk were less than 3.5 microns in diameter while 70 to 94% of those in Holstein milk were under the same limit. Campbell found that fat globules were larger in the first month after calving; during the next two months they declined rapidly in size and then decreased in size slowly until the end of lactation. The decline was more rapid in milk of Holsteins than in the milk of Guernseys.

Sharp (1940) whimsically estimated that the fat globules in a quart of Guernsey milk, if laid side by side, would form an invisible thread 5,860 miles long; that their combined surface areas would equal 1050 square feet; and that, although it would take over a gallon of paint to cover such an area, the cow covers the surfaces of these globules with about 0.25 grams of "membrane" material.

**"Melting point" of fat.** The melting point of milk fat is not a definite temperature but rather a range of temperatures. Melting is detectable at 15°C. but complete solution is not attained below 30°C. The different glycerides, of which milk fat is composed, have different melting points. Furthermore, it is probable that those glycerides with high melting points may be soluble in those with lower melting points.

**Specific heat of fat.** Rishoi and Sharp (1938) reported specific heat values of 0.575 at 20 to 25°C., and 0.475 at 25 to 40°C.

**Density of fat.** Jenness and his co-workers (1942) found that the density of milk fat at 60°C. approximated 0.889 grams per milliliter.

**Functions of fat.** Milk fat is important in cheese making because it has a direct influence on the eating qualities of the cheese. Economically, it is significant because it is the element in milk by which the value of the milk for cheese making is commonly measured. It is directly related to the yield of cheese. Many of the steps of cheese making are regulated by the desire of the maker to control the quantity and sometimes the physical condition of the milk fat.

Milk fat affects *flavor* in cheese because it undergoes hydrolysis when acted upon by enzymes known as lipases. The fatty acids liberated in this reaction have characteristic flavors. Properly blended with the other flavoring substances in cheese they are the desired end-products of the ripening process; but in excessive amounts, as for example in rancid cheese, they can be highly objectionable.

Milk fat as it occurs in fresh milk contributes a bland *flavor* which can be detected and appreciated for a long time in some varieties of cheese. This richness and delicacy of flavor is highly pleasing.

The consistency of milk fat and its melting properties impart mellowness and smoothness to the *body* of cheese. Substitution of water for fat in order to attain this desirable consistency is possible only to a limited degree in any given variety of cheese.

The *color* of milk fat contributes its characteristic hue to cheese.

**Fat-like substances.** Fat-like substances in milk are sterols and phospholipides. It is not known whether they have any direct influence on the cheese-making or ripening processes. Phospholipides have been identified with reactions responsible for defective flavors in milk and butter. It is possible and not unlikely that they may undergo significant changes during cheese ripening.

## MILK PROTEINS

All proteins contain nitrogen, carbon, hydrogen and oxygen; most of them contain sulfur; and some, notably casein, contain phosphorus. They are complex molecules and, although they have been studied many years, knowledge of them is still incomplete. Just as milk fat can be broken down into its component fatty acids and glycerol, so proteins yield amino acids on hydrolysis. The principal proteins of milk are casein, lactalbumin, and lactoglobulin.

**Identity of casein.** Casein, the principal protein of milk is identified as a phosphoprotein because it contains phosphorus. Van Slyke and Bosworth (1915) studied the insoluble portion of milk removed by the Pasteur-Chamberland filter. When this portion was purified it consisted of neutral calcium caseinate (tetra-calcium caseinate) and neutral di-calcium phosphate. They pointed out that it was possible to effect nearly complete separation of phosphate from caseinate by centrifugal methods. Van Slyke (1928) could not understand how the tetra-calcium caseinate could exist alone at the pH of milk and suggested that the casein existed in the form of a mixture of tetra-calcium caseinate with a more acid caseinate.

Ramsdell and Whittier (1944) studied the calcium caseinate complex by means of a supercentrifuge rotating at 50,000 revolutions per minute. They calculated that the complex consisted of 4.80% tricalcium phosphate and 95.20% calcium caseinate. The calcium caseinate portion of the complex contained: 1.18% calcium, 0.78% phosphorus, 15.34% nitrogen, 52.29% carbon, 6.919% hydrogen, 0.762% sulfur, and 22.73% oxygen. These results agreed very well with analyses of casein prepared by acid precipitation.

**Physical state of casein.** Calcium caseinate in milk exists in the form of minute, gelatinous particles in suspension in the liquid phase. These particles can only be seen with the ultramicroscope. They can be removed from milk by a high-speed centrifuge and by special unglazed porcelain filters. They will not pass through a dialyzing membrane. Calcium caseinate is a prominent constituent of the slime found in the bowl of a centrifugal cream separator. Van Slyke and Bosworth (1915), after passing 100 pounds of milk through a cream separator, found that the slime consisted of 86.3% calcium caseinate. All of these facts indicate the degree of dispersion of calcium caseinate in milk.

**Coagulation of casein by acid.** When milk sours, lactic acid is formed from lactose by the action of bacteria. Lactic acid produces a definite physical and chemical change in milk casein. First, as the acid develops in the milk, it gradually combines with the calcium of the calcium caseinate to form calcium lactate and calcium-free protein. This action is complete at approximately 4.7 pH at a temperature of 20 C. At this acidity and temperature the calcium-free protein forms a jelly-like mass, if the milk has been standing undisturbed; if the milk has been stirred, then the protein forms a white, flocculant precipitate or curd which soon settles out of the serum. If acid continues to develop, then the calcium-free casein tends to disperse again. At higher temperatures the acid precipitation of calcium caseinate occurs at a higher pH level than 4.7. If acid is being added to milk, as it is in the manufacture of commercial casein, less will be required to precipitate the caseinate at a higher temperature. Acid coagulation of milk casein is the means of manufacturing many kinds of cheese, including the well-known Cottage cheese.

Calcium-free casein is insoluble in water at pH 4.7. If an alkali or an acid is added to such a mixture, the protein will tend to disperse and form the finely divided, minute, gelatinous particles characteristic of its physical condition in fresh milk.

Calcium caseinate of milk can be precipitated or coagulated by other agents than acid.

**Coagulation of casein by heat.** Heating milk under certain conditions can precipitate the milk casein. This is a complicated reaction which many theories have sought to explain. Some of the factors known to influence it are: temperature and duration of heating, hydrogen ion concentration (pH), salt balance, physical condition of the protein in respect to concentration, and previous heat treatment. Cheese makers use the property of heat coagulability to make certain unusual varieties of cheese.

**Coagulation of casein by salts.** Calcium caseinate in milk may be precipitated by saturating milk with such compounds as common salt, magnesium sulfate, ammonium sulfate, etc., at ordinary temperatures. It is precipitated also by small amounts of solution of alum, zinc sulfate, and other metallic salts. When milk is heated to 95° to 113°F., the calcium caseinate may be precipitated by calcium chloride and some other salts.

**Coagulation of casein by rennin.** The principal method of coagulating casein in the making of cheese is by the action of rennin. Rennin is an enzyme obtained commercially in the extract of the fourth stomach of young calves. Bosworth (1913) believed that the rennin acted upon calcium caseinate by hydrolytic cleavage. In this action calcium paracaseinate was formed. The calcium paracaseinate of fresh milk was only precipitated in the presence of soluble calcium salts. In the making of cheese, the curd formed by the action of rennin on milk at 30°C. is jelly-like, firm, and elastic.

Some bacteria elaborate a rennin-like enzyme which is capable of forming calcium paracaseinate from milk casein. Cheese makers know this effect as "sweet-curdled" milk, and recognize it as an indication of careless methods of milk production.

**Action of acid on calcium paracaseinate.** Calcium paracaseinate, like calcium caseinate, is changed by acidity developed during cheese making. Cheddar cheese makers have known for many years that the silky threads formed by touching a piece of curd to a hot iron and then withdrawing it carefully are an indication of acidity in the curd. Van Slyke and Hart (1902) observed that as much as 80% of the calcium paracaseinate might be in a salt soluble form within a few hours from the start of cheese making; this only occurred when the acidity increased. In the purified form this brine-soluble product could be drawn out into long, silky threads. Van Slyke and Bosworth (1913) finally concluded that this salt-soluble compound was monocalcium paracaseinate.

In Camembert cheese, in which more acid develops than in Cheddar, there is enough acid to combine with all of the calcium of the calcium paracaseinate. This explains why Bosworth (1907) found only calcium-free paracasein in Camembert cheese after the acid had fully developed.

**Lactalbumin and lactoglobulin.** After the calcium caseinate of milk has been coagulated by acid or rennin action, other proteins still remain in the whey. The lactalbumin and the lactoglobulin are the principal ones. Van Slyke and Bosworth (1916) observed that these proteins passed through a porcelain filter, thus indicating that they were either in solution or in a more finely divided colloidal suspension than calcium caseinate. In cheese making these albumins are usually called "whey proteins."

Whey proteins are coagulated by the combined action of heat and acid in the making of Ricotta and related varieties of cheese. Okuda and Zoller (1921) found that the optimum acidity for precipitation of these proteins was pH 4.5.

**Functions of milk proteins.** Some of the functions of milk proteins in cheese making are quite clear, others are obscure or unknown.

Calcium caseinate is the mother substance of the curd. The curd imprisons fat globules and insoluble phosphates. It holds the whey with its soluble constituents much as a sponge holds water. The manipulations of cheese making regulate the final whey content of the curd and the cheese and in this manner determine largely the firmness, consistency, elasticity, and plastic properties of the cheese. The cheese maker refers to these characteristics of the cheese by the collective term "body."

The proteins of the curd undergo distinctive changes that are responsible for many characteristics of the finished cheese. The changes caused by the acid of bacterial fermentation of lactose begin during curd making. Other milk bacteria, as well as microorganisms added in cultures, help to convert these proteins into simpler substances. The enzymes of rennet extract, milk enzymes, and other added enzymes act upon these protein materials. In this manner the milk proteins are changed into simpler compounds which eventually affect both the body and flavor of the cheese.

In this explanation of their functions in cheese making, the milk proteins have all been considered as undergoing similar changes. This seems justified at this time because it does not seem probable that the whey proteins remaining in the cheese could entirely escape the actions of the biological agents of the ripening processes. That this assumption is probably correct is indicated by the favorable preliminary results of attempts to develop a blue-mold variety of cheese from whey proteins (Reed, 1946).

The changes in the proteins during cheese ripening will be considered again in discussions of the ripening of cheese.

## MILK SUGAR

**Identity of milk sugar.** Lactose, or milk sugar, is the carbohydrate of milk. It contains carbon, hydrogen, and oxygen in the proportions $C_{12}\ H_{22}\ O_{11}$. It is classified chemically with sucrose and maltose, and is a disaccharide. Lactose can be hydrolyzed by the enzyme lactase or by the action of dilute acid and heat. The products of its hydrolysis are the two simple sugars, glucose and galactose. Certain microorganisms commonly used in the dairy industry convert lactose into organic acids, chief of which is lactic acid.

**Functions of lactose.** The conversion of lactose into lactic acid is essential in the manufacture of cheese for several reasons:

(1) Some of the lactic acid combines with calcium compounds of milk to form soluble calcium salts, both lactates and phosphates. These salts are essential in the coagulation of milk with rennet. The speed of the coagulation can be regulated to

a certain degree by the control of the lactose-to-lactic acid fermentation.

(2) As lactic acid develops in the curd formed by rennet action, it removes some of the calcium from the calcium paracaseinate. This action is believed to be one factor which causes the expelling of moisture from the curd. The monocalcium paracaseinate formed is associated with the stringing of curd on the hot iron and with the development of the plastic properties so essential for successful matting of Cheddar cheese curd and for the shaping of the pasta filata types of Italian cheese.

(3) The development of lactic acid in the souring of milk gradually removes the calcium from calcium caseinate until finally the calcium-free casein precipitates. This action is typical of the manufacture of Cottage cheese and commercial casein.

(4) The lactic acid formed from lactose affects the growth of microorganisms in the curd and cheese. It inhibits some harmful types which might produce gas or undesirable flavors; it establishes conditions favorable for beneficial reactions of bacteria and enzymes.

(5) If excessive or insufficient amounts of lactose are retained in the curd, then the maker can expect to have defects in flavor, body, texture, color or appearance of the cheese; usually more than one of these characteristics are affected.

**Residual lactose.** Approximately one-fifth of the lactose is decomposed during the souring of milk by the action of *Streptococcus lactis* type of organisms, according to Van Slyke and Bosworth (1916). In cheese making the lactose disappears at rates characteristic of the variety of cheese. These same workers (1907) observed that the lactose of Cheddar cheese might be reduced to less than 0.5% in 24 hours after making and that it entirely disappeared in about 2 weeks. Foster, Garey and Frazier (1942) observed 0.3 to 1% of residual lactose in the traditional type of Brick cheese several weeks after it was made.

**Utilization of lactose.** Lactose is the chief constituent of the dry matter of whey. Whey is a by-product of cheese making. Complete and profitable utilization of this by-product is the mark of an efficient manufacturing operation. Whey is a valuable food for stock and most of it is used for this purpose in liquid, concentrated, or dried form (Price, Bohstedt and Rupel, 1943). Large amounts of lactose are utilized in the form of concentrated whey for cheese foods, candies, and, to a more limited extent, in sweet baked goods. Some lactose is refined and used in infant foods and pharmaceuticals. Crude lactose was used in large amounts in World War II for the manufacture of penicillin, and it is still being used for this purpose.

### MILK SALTS

The salts of milk represent about 0.9% of the milk, although its "ash" content, that portion which remains after heating milk to low-red heat, approximates 0.7%. Some of the milk salts, like the citric acid of the citrates, are volatilized in the ashing process.

**Identity of milk salts.** The identity of the compounds in which the constituents of the ash exist in milk can only be surmised. Van Slyke and Bosworth (1915) suggested the arrangement presented in table 1:3. As the ash constituents of milk increase, the lactose content of the milk tends to decrease. Sharp (1938) pointed out that the relationship also applies to milks of other mammals.

TABLE 1:3. A POSSIBLE ARRANGEMENT OF MINERAL ELEMENTS AS SALTS OF MILK
(Van Slyke and Bosworth, 1915)

| *Salt combinations of milk* | *Percentage of milk* | *Percentage of salts* |
|---|---|---|
| Calcium with protein | 3.20 | 78.02 |
| Dicalcium phosphate | 0.175 | 4.27 |
| Calcium chloride | 0.119 | 2.90 |
| Monomagnesium phosphate | 0.103 | 2.51 |
| Trisodium citrate | 0.222 | 5.41 |
| Tripotassium citrate | 0.052 | 1.26 |
| Dipotassium phosphate | 0.230 | 5.61 |

**Significance of milk salts.** In cheese making the salts containing calcium are particularly significant. Soluble calcium salts are essential for coagulation of milk casein by rennin. Acid development in milk increases the amounts of the soluble calcium salts which improve rennin efficiency.

Chlorides in milk, if present in larger than normal amounts, may indicate abnormal milk or milk from diseased udders. Such abnormal milk is undesirable in cheese making. Davies (1938) observed from 0.07% to 0.12% in 7,802 samples from Guernsey, Shorthorn and Friesian cows. Sharp and Struble (1935) stated that high chloride values were found in colostrum, and in milk from cows late in lactation, as well as in milk from diseased udders. The first and last milks drawn from quarters infected with mastitis were high in chlorides while the middle milk often fell within the normal range. Such criteria of normal milk must obviously be applied cautiously in factory practice.

Cheese makers have questioned the effect of pasteurizing milk on solubility of calcium. Rupp (1913) declared that no appreciable chemical changes were caused by holder-pasteurization. Holding at 155° F. (68.3°C.) for 30 minutes did not make the phosphates of lime and magnesium insoluble. Bell (1925) observed that measurable amounts of calcium and phosphorus were rendered insoluble only in milks heated to 170°F. and above. Such treatments are in excess of pasteurization requirements.

## PIGMENTS OF MILK

The constituents of milk that are not in solution give milk its white color.

**Carotene.** The pigments which impart to milk its yellowish color are carotene and, to a much smaller extent, xanthophyll. The yellow color of milk depends directly upon the carotene in the feed consumed by the cow. Green grass pasture, properly cured alfalfa hay, A.I.V. silage, or molasses silage made with green grass or alfalfa are all rich in carotene.

These yellow pigments are dissolved in the milk fat. Even with identical amounts of carotene, the milk appears more yellow in color when the fat globules are large in size, as they are in milk of the Guernsey and Jersey breeds.

**Riboflavin.** Riboflavin is the pigment which imparts to whey its greenish-yellow color. It is soluble in the water phase of the milk. Riboflavin is also known as vitamin G or $B_2$.

**Functions of pigments.** The functions of the pigments of milk in cheese making are probably not essential although they may be of some real importance.

The carotene of milk is significant because it is converted into vitamin A when the milk, or cheese made from it, is used for food. Vitamin A is present with carotene in milk fat. In the milk of some breeds (Guernsey, for example) there is more carotene in proportion to vitamin A than in the milk of other breeds (Holstein). Usually the natural yellow color of milk fat is desired in the manufactured product but in a few varieties of cheese, particularly the blue-mold type, every effort is made to keep the yellow color at a minimum. This is done to suit certain trade preferences. Some manufacturers meet this demand by limiting the production of the cheese to seasons when cows receive low-carotene diets; others bleach the milk fat; homogenization has a limited application for concealing the yellow color of the natural milk fat.

Riboflavin is an essential growth factor for *Lactobacillus casei*, an organism which functions in the ripening of cheese.

Riboflavin in whey is so desirable that dried whey is sometimes fortified with it in order to standardize the value of the dried whey as a food for livestock. Such profitable utilization of the by-product of the cheese industry is becoming an important factor in determining the efficiency of factory operation.

## Milk Vitamins

Milk contains many vitamins. To attempt to discuss them all individually would be entirely beyond the scope of this text. The extensive review of milk vitamins by Sommer (1946 pp. 45-66) is recommended to those interested in a concise, informative discussion of this subject.

Irwin (1939) lists the following vitamins in milk: vitamin A, thiamin (vitamin $B_1$), ascorbic acid (vitamin C), vitamin D, riboflavin (vitamin $B_2$ or G), nicotinic acid, vitamin $B_4$, vitamin $B_6$, factor W, pantothenic acid, vitamin E, vitamin K, and the "grass juice factor."

Some, if not all, of the fat-soluble vitamins A, D, E, and K are found in the finished product in proportion to the amount of milk fat retained by the cheese. The other vitamins are undoubtedly found in the cheese in proportion to the amounts of whey retained.

**Functions of vitamins.** The functions of the vitamins of milk in cheese making can only be surmised. It seems probable that the growth of microorganisms involved in the making and ripening of cheese may be stimulated by or even be dependent upon, the presence of certain of these vitamins. It is known that some bacteria require certain growth factors. The work of Snell, Strong, and Peterson (1939) demonstrated that some species of *Lactobacillus* and *Propionibacterium* need pantothenic acid for good growth. Snell and Peterson (1940) showed that this same growth factor was required by *Lactobacillus helveticus*. Snell and Strong (1939) found that some species of *Lactobacillus* required riboflavin.

The works of these investigators have been selected among others to indicate the significance of some of the vitamins found in milk upon the growth of certain microorganisms which are known to be important in the manufacture of cheese. It is probable that, as the information of these and similar studies is applied, it may be possible to explain such phenomena of cheese making as slow acid development, "non-acid" milk, some starter failures, and perhaps defects in the curing of cheese. It may be that the common preference of cheese buyers for summer cheese as opposed to "fodder" cheese reflects in part the effect of the superior vitamin content of summer milk upon the growth and activity of microorganisms essential for cheese making and ripening.

### MILK ENZYMES

Enzymes are organic substances formed by living cells of animals, microorganisms and plants. They are capable of hastening chemical reactions. Their actions do not depend upon the living cells which formed them. They themselves are not used up in their reactions and they do not become a part of the compounds formed. They are biological catalysts. A few enzymes have been isolated; they are all proteins.

It is customary to name the enzyme by taking the name of its substrate, that is the substance upon which it acts, and adding to it the suffix "ase." There are many exceptions, especially among the enzymes which have been known for many years; rennin, which acts on calcium caseinate, is a notable example of particular interest to cheese makers.

The activity of an enzyme is affected by many factors including: the concentrations and proportions of substrate and enzyme, temperature, pH, presence of salts, and oxidation-reduction potential.

Some of the enzymes in normal milk are secreted with the milk and are sometimes spoken of as *inherent* enzymes of milk; others are elaborated by the bacteria in milk. The enzymes commonly present in normal milk from healthy cows are: proteases, lipases, and phosphatases. Many others have been found in milk; Espe (1938 p. 52), who says the existence of some enzymes in milk can be questioned, also lists the following: diastase, lactase, salolase, catalase, peroxidase, aldehydrase, reductase, and oleinase.

**Functions of enzymes.** The functions and actions of milk enzymes in the making of cheese have attracted attention for many years. Babcock and Russell (1897), after first establishing the presence of a proteolytic enzyme inherent in milk, stated: ". . . it is our present belief that the influence of the inherent milk enzymes is so prominent as to challenge comparison with the effect of biological activity." They held cheese under chloroform to prevent bacterial growth and observed that protein decomposition was typical of normal year-old cheese.

There are probably several lipases inherent in milk. Others may be elaborated by milk bacteria. Herrington and Krukovsky (1939) distinguished two by differences in sensitivity to formalin. The lipases of milk hydrolyze the fat and form fatty acids which give milk and its products "off" or rancid flavors. Krukovsky and Herrington (1942) and Hlynka and Hood (1942) observed that slight hydrolysis caused deterioration in flavor without definite rancidity. Krukovsky and Herrington (1939) accelerated lipolysis in cold milk, at 41°F. or lower, by warming it to 86°F. and then cooling it below 50°F. again. Such treatments can occur when milk is not properly handled on the farms, particularly in cold weather when warm and cold milks may be mixed together. Mixing milk containing large amounts of lipase with normal milk immediately after milking will prevent rancidity, according to Tarassuk and Henderson (1942).

Lane and Hammer (1939a) observed that the acidities of fats from raw-milk cheese were higher than those from pasteurized-milk cheese. They associated this effect (1939b) with normal flavor development in Cheddar cheese. Tuckey (1941), having observed significant increases in the acid number of the fat in ripening Cheddar cheese, stimulated lipase action by adding homogenized, raw cream to pasteurized skim milk. A rancid flavor was produced which persisted in the cheese for at least 4 months.

Hood, Hlynka and Gibson (1941), during a series of investigations of the rancidity defect in Canadian Cheddar cheese, produced rancid cheese by adding lipase to the milk or by homogenizing milk. Later Hlynka, Hood and Gibson (1943) induced rancidity and unclean flavors in cheese by making it from milk which had been agitated vigorously under different temperature conditions. This method of activating milk lipase is most effective, according to Krukovsky and Sharp (1938), when the fat is at least partially liquefied; Hood and his co-workers verified this with their cheese-making experiments.

Pasteurization of milk inactivates lipases which may be in it. Such milk can be homogenized for cheese-making purposes without fear of rancidity in the finished product. Steam-jet heaters for pasteurizing milk must be operated with special care because the extreme agitation of milk usually produced by these devices tends to induce rancidity in the cured cheese.

The flavors of some of the fatty acids can be identified in ripened cheese. Homogenization to activate lipase is being used extensively in the manufacture of blue cheese. This is a patented process developed as a result of experimental work by Lane and Hammer (1938) at the Iowa Agricultural Experiment Station. Further developments can be expected in the use of lipases, and possibly other enzymes, as agents for accelerating the ripening of cheese (Babel, Stewart and Hammer, 1942; Babel and Hammer, 1945).

Phosphatases in milk serve no useful function in cheese making so far as is now known. Phosphatases are of interest because they are inactivated by proper pasteurizing treatments. The presence of these enzymes in heated milk are therefore used to detect inefficient pasteurization. Phosphatases apparently survive the cheese-making and curing processes and their presence in cheese is believed to be indicative of the use of raw milk or improperly pasteurized milk in its manufacture.

The other enzymes which have been mentioned as being present in milk have not been associated as yet with any known function in the making of cheese.

## MILK GASES

The gases recognized in milk are carbon dioxide, oxygen, and nitrogen. Traces of other atmospheric gases and ammonia may be present.

Van Slyke and Baker (1919) observed about 10% carbon dioxide by volume in normal milk. As the gas content of the milk increased the titratable acidity decreased. Van Slyke and Keeler (1920) reported that both hand and machine milking produced milk with 4.5% carbon dioxide by volume, and that pasteurization usually reduced this amount to less than 2.5%. Frayer (1940) found that, even in the udder, oxygen was present in the milk. He associated exhaustion of oxygen and the increase of carbon dioxide with bacterial growth in milk. Noll and Supplee (1941) measured the gas contents of 63 samples of commercial milk and reported the results in volume per cents as follows: oxygen, 0.47%; nitrogen, 1.29%; carbon dioxide, 4.45%. Their observations indicated that the effects of temperature and pressure on the gas content of milk followed the physical laws governing the solubility of gases in liquids.

**Significance of gases.** It is possible that carbon dioxide dissolved in milk may slightly hasten its coagulation, because this dissolved gas increases the acidity of the milk. It has been added to milk to hasten rennet coagulation after high-temperature heat treatments.

The relation between oxygen content of milk and bacterial growth is of interest because it is associated with the rate of reduction of the methylene blue and resazurin tests for milk quality.

In most types of cheese there is a scarcity of oxygen as a normal and desirable condition; an exception is the mold ripened type in which some oxygen is a necessity. It seems probable that the gases in milk are not of any great practical significance in the manufacture or curing of cheese.

## REFERENCES

Babcock, S. M. and Russell, H. L. (1897). Wis. Agr. Expt. Sta., 14th Ann. Report, 161.

Babel, F. J. and Hammer, B. W. (1945). J. Dairy Sci., *28*, 201.

Babel, F. J., Stewart, G. F. and Hammer, B. W. (1942). J. Dairy Sci., *25*, 730.

Bell, R. W. (1925). J. Biol. Chem., *64*, 391.

Bosworth, A. W. (1907). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 5.

Bosworth, A. W. (1913). J. Biol. Chem., *15*, 230.

Campbell, M. H. (1932). Vt. Agr. Expt. Sta., Bul. 341.

Davies, W. L. (1938). J. Dairy Res., *9*, 327.

Espe, Dwight L. (1938). Secretion of Milk. Ames, Iowa. Collegiate Press, Inc.

Foster, Edwin M., Garey, John C. and Frazier, William C. (1942). J. Dairy Sci., *25*, 313.

Frayer, J. M. (1940). Vt. Agr. Expt. Sta., Bul. 461.

Herrington, B. L., and Krukovsky, V. N. (1939). J. Dairy Sci., *22*, 127.

Hlynka, I. and Hood, E. G. (1942). J. Dairy Sci., *25*, 389.

Hlynka, I., Hood, E. G., and Gibson, C. A., (1943). J. Dairy Sci., *26*, 1111.

Holland, E. B. and Garvey, Mary E., Pierce, H. B., Messer, Anne C., Archibald, J. G., Dunbar, C. O., (1923). J. Agr. Res., *24*, 365.

Hood, E. G., Hlynka, I., and Gibson, C. A., (1941). Canad. Dairy and Ice Cream J., *20*, No. 3: 26.

Irwin, Margaret House, (1939). Wis. Agr. Expt. Sta., Bul. 447.

Jenness, Robert, Herreid, E. O., Caulfield, W. J., Burgwald, L. H. Jack, E. L., and Tuckey, S. L., (1942). J. Dairy Sci., *25*, 949.

Krukovsky, V. N., and Herrington, B. L., (1939). J. Dairy Sci., *22*, 137.

Krukovsky, Vladimir N. and Herrington, B. L., (1942). J. Dairy Sci., *25*, 237.

Krukovsky, V. N. and Sharp, Paul F., (1938). J. Dairy Sci., *21*, 671.

Lane, C. B. and Hammer, B. W. (1939a). Iowa State College J. Sci., *13*, 149.

Lane, C. B. and Hammer, B. W. (1939b). J. Dairy Sci., *22*, 432.

Lane, Clarence B. and Hammer, Bernard W. (1938) (to Iowa State College Alumni Association, Ames, Iowa) U. S. Patent 2,132,077. Oct. 4, 1938.

Noll, C. I. and Supplee, G. C., (1941) J. Dairy Sci., *24,* 993.

Okuda, Yuzuru and Zoller, Harper F., (1921). Ind. and Eng. Chem., *13,* 515.

Palmer, L. S. and Wiese, H. F., (1933). J. Dairy Sci., *16,* 41.

Price, W. V., Bohstedt, G., and Rupel, I. W., (1943). Wis. Agr. Expt. Sta., Circ. 340.

Ramsdell, G. A. and Whittier, E. O., (1944). J. Biol. Chem., *154,* 413.

Reed, O. E. (1946). J. Milk Technol., *9,* 173.

Rishoi, A. H., and Sharp, P. F., (1938). J. Dairy Sci., *21,* 399.

Rupp, Philip (1913). U.S.D.A., Bur. An. Ind., Bul. 166.

Sharp, Paul F., (1938). J. Dairy Sci., *21,* 127.

Sharp, Paul F., (1940). J. Dairy Sci., *23,* 771.

Sharp, Paul F. and Struble, Earle B., (1935). J. Dairy Sci., *18,* 527.

Snell, E. E., and Peterson, W. H., (1940). J. Bact., *39,* 273.

Snell, E. E., and Strong, F. M., (1939). Enzymologia, *6,* 186.

Snell, E. E., Strong, F. M. and Peterson, W. H., (1939). J. Bact., *38,* 293.

Sommer, Hugo H., (1946). Market Milk and Related Products. Madison, Wis. Published by the author.

Tarassuk, N. P. and Henderson, J. L., (1942). J. Dairy Sci., *25,* 801.

Tuckey, S. L., (1941). Nat. Butter and Cheese J., *32,* No. 9: 12.

U. S. Public Health Service (1939). Public Health Bul. 220.

Van Slyke, L. L., (1928). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 139.

Van Slyke, L. L. and Baker, J. C., (1919). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 69.

Van Slyke, L. L. and Bosworth, A. W., (1907). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 4.

Van Slyke, L. L. and Bosworth, A. W., (1913). J. Biol. Chem., *14,* 231.

Van Slyke, L. L. and Bosworth, A. W., (1915). J. Biol. Chem., *20,* 135.

Van Slyke, L. L. and Bosworth, A. W., (1916). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 48.

Van Slyke, L. L. and Hart, E. B., (1902). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 214.

Van Slyke, L. L. and Keeler, R. F., (1920). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 78.

# CHAPTER 2

## VARIATIONS IN THE PROPORTIONS OF CONSTITUENTS OF MILK

The tendency toward uniformity of composition in the mixed milk of many cows is the justification for presenting the data in this discussion. Such mixed milk is typical of that received in modern dairy plants. But there are basic factors which cause broad changes even in the composition of mixed milk. These changes are highly significant in cheese factory practices because they affect factory efficiency and the operations of making and curing.

**Variations in percentages of milk constituents.** The composition of the milk from any cow varies from milking to milking and from day to day throughout her entire lactation period. The mixed milk obtained from a herd of cows is not as variable from day to day as that of any individual. The mixed milk of many herds is still more uniform in percentage composition.

### "AVERAGE" COMPOSITION OF MILK

Data will be presented to show the "average" composition of milk as it is affected by such factors as breeds, seasons, stage of lactation, and the like. The reader should not be deceived into thinking that milk composition can be so simply stated with complete accuracy. Averages are merely commonly used estimates of true values we shall never know exactly, even if they exist.

Jacobsen (1936) assembled analyses of 100,000 samples of milk. These samples were taken over a period of 16 months. Some of his data are summarized in table 2:1. These averages show a notable regularity of increase of fat and solids in the proportion of 1% of fat to 0.4% solids. This relation can be expressed by the formula:

$$\text{Per cent solids-not-fat} = 0.4 \text{ Fat} + 7.07$$

Jacobsen pointed out that there were seasonal variations in this relation. From December to May the calculated values agreed very well with actual values of solids-not-fat, when the milk

TABLE 2:1. AVERAGES SHOWING RELATION OF FAT TO OTHER SOLIDS IN PRODUCERS' MILK IN NEW ENGLAND STATES

(Jacobsen, 1936)

| *Fat* | *Solids-not-fat* | *Ratio of fat to solids-not-fat* |
|---|---|---|
| % | % | |
| 2.8 | 8.19 | 1: 2.93 |
| 2.9 | 8.23 | 1: 2.84 |
| 3.0 | 8.27 | 1: 2.76 |
| 3.1 | 8.31 | 1: 2.68 |
| 3.2 | 8.35 | 1: 2.60 |
| 3.3 | 8.39 | 1: 2.54 |
| 3.4 | 8.43 | 1: 2.48 |
| 3.5 | 8.47 | 1: 2.42 |
| 3.6 | 8.51 | 1: 2.36 |
| 3.7 | 8.55 | 1: 2.31 |
| 3.8 | 8.59 | 1: 2.26 |
| 3.9 | 8.63 | 1: 2.21 |
| 4.0 | 8.67 | 1: 2.17 |
| 4.1 | 8.71 | 1: 2.12 |
| 4.2 | 8.75 | 1: 2.08 |
| 4.3 | 8.79 | 1: 2.04 |
| 4.4 | 8.83 | 1: 2.00 |
| 4.5 | 8.87 | 1: 1.97 |
| 4.6 | 8.91 | 1: 1.93 |
| 4.7 | 8.95 | 1: 1.90 |
| 4.8 | 8.99 | 1: 1.87 |
| 4.9 | 9.03 | 1: 1.84 |
| 5.0 | 9.07 | 1: 1.82 |
| 5.1 | 9.11 | 1: 1.79 |
| 5.2 | 9.15 | 1: 1.76 |
| 5.3 | 9.19 | 1: 1.73 |
| 5.4 | 9.23 | 1: 1.71 |
| 5.5 | 9.27 | 1: 1.69 |
| 5.6 | 9.31 | 1: 1.66 |
| 5.7 | 9.35 | 1: 1.64 |
| 5.8 | 9.39 | 1: 1.62 |
| 5.9 | 9.43 | 1: 1.60 |
| 6.0 | 9.47 | 1: 1.58 |

samples contained from 3.2% to 4.8% fat; during June and October the calculated values of solids-not-fat averaged approximately 0.1% too low; and during July, August, and September they averaged about 0.1% too high. The data of table 2:1 show that the amounts of solids-not-fat per unit of fat decreased as the fat in the milk increased.

## FACTORS AFFECTING MILK COMPOSITION

**Influence of breed on milk composition.** Van Slyke (1908) summarized many analyses to show the average amounts of fat and proteins in milk of different breeds of cows. These values are presented in table 2:2.

TABLE 2:2. FAT AND PROTEINS IN MILK OF DIFFERENT BREEDS OF COWS

(Van Slyke, 1908)

| *Name of Breed* | *Fat* | *Proteins* | *Casein* | *Albumin* |
|---|---|---|---|---|
| | % | % | % | % |
| Holstein Friesian | 3.26 | 2.84 | 2.20 | 0.64 |
| Ayrshire | 3.76 | 3.07 | 2.46 | 0.61 |
| American Holderness | 4.01 | 3.32 | 2.63 | 0.69 |
| Shorthorn | 4.28 | 3.43 | 2.79 | 0.64 |
| Devon | 4.89 | 3.93 | 3.10 | 0.83 |
| Guernsey | 5.38 | 3.56 | 2.91 | 0.65 |
| Jersey | 5.78 | 3.68 | 3.03 | 0.65 |

Overman, Garrett, Wright, and Sanmann (1939) have assembled the representative averages of table 2:3. This table is especially useful because it also includes values for all the major constituents of milk and shows the specific gravity measurements associated with the given percentages of constituents. The range of the values observed by these workers for fat and protein are shown in table 2:4. These data emphasize the variable nature of the values upon which estimates of these averages must be based.

**Influence of individuality of animal.** No matter what the breed of the cow, the milk she produces may vary widely from day to day. Anderson (1914) presented extensive data which showed that variations in fat content of more than one per cent fat were commonly observed in two-day records of individual cows. Most of the animals, however, produced milk which varied

TABLE 2:3. MEAN PERCENTAGES OF COMPONENTS OF MILK BASED ON MILK YIELD

(Overman, Garrett, Wright & Sanmann, 1939)

| *Breed* | *No. of samples* | *Fat* | *Protein* | *Lactose* | *Ash* | *T.S.* | *S.N.F.* | *Specific gravity* |
|---|---|---|---|---|---|---|---|---|
| Ayrshire | 208 | 4.03 | 3.51 | 4.81 | 0.68 | 13.03 | 9.00 | 1.03216 |
| Br. Swiss | 428 | 3.86 | 3.48 | 5.09 | 0.72 | 13.15 | 9.30 | 1.03170 |
| Guernsey | 321 | 5.03 | 3.90 | 4.97 | 0.74 | 14.63 | 9.60 | 1.03368 |
| Holstein | 268 | 3.41 | 3.30 | 4.89 | 0.68 | 12.27 | 8.86 | 1.03238 |
| Jersey | 199 | 5.05 | 3.79 | 5.00 | 0.70 | 14.54 | 9.49 | 1.03338 |
| Guernsey-Holstein cross | 1002 | 4.21 | 3.65 | 4.93 | 0.72 | 13.54 | 9.30 | 1.03292 |
| All | 2126 | 4.14 | 3.58 | 4.96 | 0.71 | 13.39 | 9.25 | 1.03261 |

TABLE 2:4. RANGE OF VALUES FOR PERCENTAGES OF FAT AND PROTEIN IN THE MILK FROM DIFFERENT BREEDS

(Overman, Garrett, Wright and Sanmann, 1939)

| *Breed* | *Fat* | | *Protein* | |
|---|---|---|---|---|
| | *minimum* | *maximum* | *minimum* | *maximum* |
| | % | % | % | % |
| Ayrshire | 2.92 | 5.66 | 2.92 | 4.58 |
| Brown Swiss | 2.92 | 6.48 | 2.60 | 5.74 |
| Guernsey | 3.65 | 7.66 | 2.65 | 5.45 |
| Holstein | 2.60 | 6.20 | 2.44 | 6.48 |
| Jersey | 3.28 | 8.37 | 2.93 | 5.83 |
| Guernsey-Holstein cross | 2.72 | 7.50 | 2.65 | 6.25 |

not over one per cent of milk fat in the same period. Table 2:5 shows some of Anderson's data on individual variations. Turner (1936) stated that fat tests of herd milk might vary as much as 1% from day to day in the Jersey breed and somewhat less in the milk of lower testing breeds. Such observations emphasize the variability of milk composition of individual animals within the herd.

**Influence of stage of lactation.** The composition of milk changes with the stage of lactation.

At the time of calving, the fat, total solids, and specific gravity of the colostrum milk are high. These values decline rapidly until the milk becomes "normal" in composition. Garrett and Overman (1940) pointed out that calcium, magnesium, sodium, phosphorus, and chlorine were all present in relatively large amounts in the milk at parturition but declined rather rapidly

TABLE 2:5. PERCENTAGE DISTRIBUTION OF VARIATIONS IN MILK-FAT TESTS OF INDIVIDUAL ANIMALS

(Data from Anderson, 1914)

| *Source* * | *Total number of cows* | *Variations in per cent fat* | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.0 to 1.0% | 1.1 to 2.0% | 2.1 to 3.0% | 3.1 to 4.0% | 4.1 to 5.0% | 5.1 to 6.0% |
| | | % | % | % | % | % | % |
| A | 1000 | 63.2 | 26.7 | 7.7 | 1.6 | 0.7 | 0.1 |
| B | 1000 | 69.1 | 24.7 | 5.0 | 1.1 | 0.1 | 0.0 |
| C | 600 | 74.2 | 20.2 | 4.7 | 0.5 | 0.3 | 0.0 |

* A—Two-day, semi-official records of 1000 Jersey cows on register-of-merit tests.

B—Two-day, semi-official records of 1000 Holstein-Freisian cows.

C—Two-day records of 600 individuals, herd conditions.

after the first few hours. Potassium, which was low at parturition, tended to increase toward normality. Table 2:6 shows the rapidity and extent of changes in some of the milk constituents after calving. The proportions of the milk constituents in the first milk obtained after calving indicate clearly why manufacturers of dairy products object to the delivery of colostrum with the regular milk supply.

TABLE 2:6. THE COMPOSITION OF COLOSTRUM
(Garrett and Overman, 1940)

| *Time after calving* | *Specific gravity* | *Total solids* | *Ash* | *Protein* | *Fat* | *Lactose* |
|---|---|---|---|---|---|---|
| | | % | % | % | % | % |
| | | | HOLSTEIN | | | |
| Parturition | 1.0537 | 27.42 | 1.37 | 13.97 | 8.45 | 3.63 |
| 6 hours | 1.0345 | 27.47 | 1.07 | 9.34 | 13.02 | 4.04 |
| 12 hours | 1.0316 | 15.63 | 0.89 | 4.77 | 5.68 | 4.29 |
| 30 hours | 1.0304 | 13.41 | 0.87 | 4.09 | 3.88 | 4.57 |
| 76 hours | 1.0314 | 13.82 | 0.85 | 3.86 | 4.68 | 4.43 |
| | | | AYRSHIRE | | | |
| Parturition | 1.0594 | 25.38 | 1.16 | 14.70 | 5.40 | 4.12 |
| 6 hours | 1.0457 | 21.15 | 1.03 | 11.36 | 4.85 | 3.91 |
| 12 hours | 1.0389 | 20.32 | 0.91 | 7.00 | 8.46 | 3.95 |
| 32 hours | 1.0346 | 11.65 | 0.87 | 4.09 | 2.31 | 4.38 |
| 72 hours | 1.0324 | 12.87 | 0.85 | 3.86 | 4.00 | 4.16 |

The changes in milk composition from month to month of the lactation period are rather gradual. They tend to follow the same trends although different individuals may show varied rates of changes both in milk composition and yield of milk. Van Slyke (1908) observed the trends of fat and proteins in milk during the lactation period. His data are shown in table 2:7. Both fat and proteins were higher during the first month of lactation than during the second month. Beginning with the second month there was a rather steady increase in fat and protein until the end of lactation. Turner (1936) assembled extensive data showing the influence of lactation on the percentage of fat in milk. He observed the least fat in milk during the first month of lactation in the Jersey breed, during the second month in the Guernsey breed, and during the third month in Ayrshire and Holstein breeds.

**Influence of season of year.** Changes in composition of milk are not as closely correlated with the season as with the stage of lactation. Overman (1945) reported the composition of milk

TABLE 2:7. INFLUENCE OF LACTATION ON PERCENTAGES OF FAT AND OF PROTEINS IN MILK

(Van Slyke, 1908)

| *Month of lactation* | *Fat* | *Proteins* | *Casein* | *Albumin* |
|---|---|---|---|---|
| | % | % | % | % |
| 1 | 4.30 | 3.16 | 2.54 | 0.62 |
| 2 | 4.11 | 2.99 | 2.42 | 0.57 |
| 3 | 4.21 | 3.04 | 2.46 | 0.58 |
| 4 | 4.25 | 3.13 | 2.52 | 0.61 |
| 5 | 4.38 | 3.25 | 2.61 | 0.64 |
| 6 | 4.53 | 3.33 | 2.68 | 0.65 |
| 7 | 4.57 | 3.40 | 2.74 | 0.66 |
| 8 | 4.59 | 3.47 | 2.80 | 0.67 |
| 9 | 4.67 | 3.57 | 2.90 | 0.67 |
| 10 | 4.90 | 3.79 | 3.01 | 0.78 |
| 11 | 5.07 | 4.04 | 3.13 | 0.91 |

throughout the year. Some of his data are presented in table 2:8. Percentages of fat, protein, and ash were lowest in the warmest months of the year; percentages of lactose on the other hand tended to be highest in the warmer months of the year. Turner (1936) assembled data from several thousand animals of different breeds to show that the lowest percentages of milk fat were produced during the warm months of the year.

The environmental temperature of the cows seems to be related to the composition of the milk produced. This is probably a partial explanation of the seasonal trends of milk composition.

TABLE 2:8. MONTHLY VARIATIONS IN THE COMPOSITION OF MILK

(Overman, 1945)

| *Month* | *No. cows* | *No. samples* | *Percentages* | | | | *Specific gravity* |
|---|---|---|---|---|---|---|---|
| | | | *Fat* | *Protein* | *Lactose* | *Ash* | |
| Jan. | 130 | 227 | 4.31 | 3.67 | 4.87 | 0.72 | 1.0331 |
| Feb. | 127 | 199 | 4.22 | 3.62 | 4.89 | 0.72 | 1.0330 |
| Mar. | 131 | 228 | 4.16 | 3.56 | 4.98 | 0.71 | 1.0328 |
| Apr. | 128 | 210 | 4.10 | 3.54 | 5.01 | 0.71 | 1.0328 |
| May | 132 | 208 | 4.10 | 3.53 | 5.04 | 0.71 | 1.0322 |
| Jun. | 124 | 201 | 3.96 | 3.45 | 5.02 | 0.70 | 1.0323 |
| Jul. | 123 | 195 | 3.95 | 3.46 | 5.01 | 0.70 | 1.0317 |
| Aug. | 116 | 173 | 3.95 | 3.54 | 5.00 | 0.69 | 1.0315 |
| Sept. | 109 | 176 | 4.10 | 3.62 | 4.96 | 0.70 | 1.0321 |
| Oct. | 112 | 182 | 4.24 | 3.66 | 4.92 | 0.71 | 1.0330 |
| Nov. | 119 | 207 | 4.27 | 3.69 | 4.88 | 0.72 | 1.0332 |
| Dec. | 128 | 220 | 4.30 | 3.65 | 4.92 | 0.72 | 1.0331 |

Low temperatures are associated with high fat content in the milk while high temperatures tend to decrease the percentages of fat and solids-not-fat in the milk.

Ragsdale and Brody (1922) recorded for 41 days the true fat content in the milk of ten cows which were given the same treatment in respect to such factors as exercise and feed. They found that a decrease of 10°F. in the environmental temperature caused an increase of 0.2% in the fat content of the mixed milk of this herd. Bartlett (1935) observed only slight reduction in the yield and in the fat and solids content of milk produced by cows subjected to artificially produced high temperatures. He suggested that temperature alone is not the only factor responsible for the downward trend of yields and fat and solids-not-fat in summer milk. Regan and Richardson (1938) reported that at temperatures above 80°F. milk flow decreased, percentage of solids-not-fat decreased, time required for rennet coagulation was lengthened, and percentage of fat and pH of milk tended to increase. They believed these trends occurred because such temperatures were above the upper limit of heat regulation of the dairy cow. When such conditions were prolonged they observed increased body temperatures and definite changes in the chemical characteristics of the milk fat as well as in the other physical differences that have been mentioned.

In the spring, when cows go from barn to pasture feeding, there is a change in the composition of the milk. This is regularly noticed in cheese factories. There is a definite increase which may approximate 0.2% fat in the milk. Cows turned into pasture are inclined to exercise more; this tends to increase the fat content of the milk. The change of food also has its effect. After a few weeks the composition of the milk tends to return to normal.

**Influence of interval between milkings.** Turner (1936) stated that, under ordinary conditions, the milk secreted by the cow tends to be uniform in fat content during the 24 hours of the day. Variations may be caused by changes in exercise, intervals between milkings, and temperature differences. Longer intervals between milkings produce more milk with a lower percentage of fat. Table 2:9 illustrates the extent of variations in percentages of fat, yields, and time of occurrence of the maximum fat test when intervals between milkings were equal.

**Influence of completeness of milking.** The amount of fat drawn from the udder with the first streams of milk is relatively small. The last milk drawn in the strippings is rich in fat. When

TABLE 2:9. YIELDS AND PERCENTAGES OF FAT OBTAINED AT EQUAL INTERVALS BETWEEN MILKINGS

(Turner, 1936. Data from American Jersey Cattle Club)

| *Milking Period* | *Milk* | *Fat* | *Period of Maximum test* |
|---|---|---|---|
| | *lb.* | *%* | *Number* |
| | Two milkings per day (821 tests) | | |
| A.M. | 13.5 | 5.25 | 269 |
| P.M. | 12.7 | 5.50 | 498 |
| | Three milkings per day (1515 tests) | | |
| A.M. | 11.3 | 5.01 | 232 |
| Noon | 9.8 | 5.55 | 705 |
| P.M. | 9.5 | 5.41 | 491 |

the milk is not completely removed from the udder it has the immediate effect of decreasing the percentage of fat in the milking. Van Slyke (1908) has shown to what extent the composition of milk varied with the fraction of milk drawn from the udder of the animal. These values are presented in table 2:10. The proteins of the milk were present in larger proportions in the first fraction and decreased as milking proceeded.

TABLE 2:10. VARIATION OF FAT AND PROTEINS OF MILK IN FRACTIONAL MILKINGS

(Van Slyke, 1908)

| *Fraction drawn* | *Milk* | *Fat* | *Proteins* | *Casein* | *Albumin* |
|---|---|---|---|---|---|
| | lb. | % | % | % | % |
| First | 3.2 | 0.76 | 3.29 | 2.67 | 0.62 |
| Second | 4.1 | 2.60 | 3.21 | 2.57 | 0.64 |
| Third | 4.6 | 5.35 | 3.10 | 2.49 | 0.61 |
| Fourth | 5.8 | 9.80 | 2.97 | 2.39 | 0.58 |
| Whole milk of same cow | .. | 5.34 | 3.12 | 2.51 | 0.61 |

**Influence of health of animal.** Both the composition and the yield of milk are affected by the health of the cow. How extensive the effects may be depends upon the condition of the animal. This is particularly true when cows are suffering from mastitis. Dahlberg, Kucera, Hening, and Hucker (1936) reported their observations on the effects of latent mastitis on the chemical composition of milk. Their studies indicated that only slight differences occurred in mixed milk regardless of the degree of infection, as long as the milk remained normal in its microscopic appearance. The slight differences they observed included decreases in lactose, specific gravity, skim milk solids, and curd tension; and increases in chlorides and albumins. These differences were not greater than variations in the chemical composition of milk from two herds of the same breed. If no milk was included from inflamed, congested or injured quarters, the chemical composition of the milk from the herd remained normal. These findings seem particularly significant because it is the mixed milk of herds infected with latent mastitis with which the cheese maker has to contend.

The public health aspect of the use of mixed milk that contains the production of some animal suffering from mastitis is a matter of concern. Definitions of milk indicate that the cow must be healthy. The Food, Drug and Cosmetic Act says that a food will be deemed to be adulterated if it is in whole or in part the product of a diseased animal. The application to cows with mastitis would seem to be clear.

**Influence of feed on milk composition.** The literature on this subject is extensive. Turner (1936) has prepared an excellent review of factors that affect the composition of milk and among them he discussed the influence of feed.

*Fat* in milk is derived from other constituents of the feed as well as from the fat in the feed. A normal ration should contain as much fat as the milk. Increasing the fat content of the ration may increase the fat in the milk temporarily as much as 12 to 20%. Fish oils, such as cod-liver oil, may cause a decrease in milk fat. The source of the fat in the ration may influence the chemical and physical properties of the milk fat. Overman and Garrett (1932) for example, showed that soybean feed could cause the milk fat to have a higher index of refraction, a higher iodine number, slightly higher mean molecular weight, and lower saponification and Polenske numbers.

*Protein* in the ration is not important in affecting milk composition. Perkins, Krauss and Hayden (1932) found such minor variations in milk composition after great extremes of protein feeding that they concluded protein was not important under practical conditions.

*Minerals* in the ration, with the exception of iodine, do not increase the mineral content of the milk sufficiently to be of practical importance.

*Carbohydrates* in the ration have little influence on milk composition unless feed is short.

*Quantity* of feed must be adequate or the flow of milk decreases. Usually this is accompanied by an increase in percentage of fat.

*Vitamins* in the feed may affect the vitamin content of the milk. Vitamin A in milk depends upon the quantity consumed as carotene and vitamin A in the feed. Vitamin $B_1$ (thiamin) can be formed by bacterial action in the rumen of the cow. Its content in milk is apparently independent of the amount in the feed of the cow. Vitamin $B_2$ (riboflavin) is relatively constant in milk and, while it comes from feed, the riboflavin apparently is not affected by variations in the amount of it in the feed. Vitamin C (ascorbic acid) may also be synthesized by the cow since the amount in the ration does not influence the ascorbic acid content of the milk greatly. Vitamin D in milk depends on the amount of this vitamin in the feed. It can be increased greatly by feeding irradiated yeast.

*Pasture* grazing induces more exercise in animals when they are first turned out in the spring. This causes an increase in fat in the milk but after several weeks the composition becomes approximately normal again. Apparently the grass stimulates milk flow but does not provide enough food value. Turner (1936) indicated that the combination of exercise and grass effects were responsible for the changes in composition.

*Drought* seasons cause changes in milk composition. Fat and protein content of milk may increase. In a severe drought Van Slyke (1896) observed slight decreases in percentage of casein and in pounds of casein for each pound of fat in the milk. Cows at that time actually suffered a degree of starvation. The changes in composition were accompanied by a shrinkage in yield of milk. Such changes in time of drought can be explained by scarcity of feed, high temperatures, or lack of water, or combinations of these factors.

Drought has a marked effect on cheese factory operations. Generally the bacteriological quality of the milk declines because of the adverse weather conditions. The cheese leaks fat, may not press together well, and in general shows the effect of milk quality deterioration. Fat losses in the whey may be excessive because of the inferior quality of milk and the abnormally high proportion of fat to casein in the milk.

## Relation of Fat to Casein in Milk

The data presented in tables 2:2 and 2:7 indicate that the relation between fat and casein is not constant. This is particularly true of the milk of individual cows. Averages of analyses of the mixed milk from many herds, however, do show a significant degree of uniformity in this relationship. Van Slyke (1908) studied the milk of 50 herds of cows in New York State from May to October; he reported that an increase of 1 per cent of fat was accompanied in general by an increase of 0.4 per cent in casein. This relation applied particularly well to mixed milk containing from 3 to 4.5 per cent fat. In milk with less than 3 per cent fat there was usually more casein per pound of fat, while in milk with more than 4.5 per cent fat there was less casein per pound of fat. This general relationship Van Slyke expressed as:

$$\text{Per cent casein} = 0.4\,(F - 3) + 2.1$$

in which F represents the per cent of fat in the milk.

This formula can be applied quite satisfactorily for calculating the casein in normal mixed milk with between 3 and 4.5 per cent of fat.

TABLE 2:11. CASEIN AND FAT IN VAT MILK IN NEW ZEALAND CHEESE FACTORIES
(McDowall, 1936. Table 81)

| *No. of Samples* | *Fat* % | *Casein* % | *No. of Samples* | *Fat* % | *Casein* % |
|---|---|---|---|---|---|
| 7 | 3.0 | 2.23 | 52 | 4.0 | 2.53 |
| 19 | 3.1 | 2.26 | 34 | 4.1 | 2.56 |
| 13 | 3.2 | 2.20 | 78 | 4.2 | 2.57 |
| 5 | 3.3 | 2.03 | 62 | 4.3 | 2.61 |
| 8 | 3.4 | 1.97 | 72 | 4.4 | 2.63 |
| 8 | 3.5 | 2.19 | 35 | 4.5 | 2.62 |
| 8 | 3.6 | 2.36 | 37 | 4.6 | 2.69 |
| 14 | 3.7 | 2.33 | 34 | 4.7 | 2.71 |
| 23 | 3.8 | 2.49 | 32 | 4.8 | 2.76 |
| 30 | 3.9 | 2.57 | 30 | 4.9 | 2.78 |

McDowall (1936) has contributed further data on this relationship and a portion of them are reproduced in table 2:11. The majority of his observations of the vat milk in New Zealand factories were made on milk containing between 3.7 and 5.0 per cent fat. Values of casein calculated from the fat content of the milk by the Van Slyke formula agree remarkably well with the amounts of casein actually observed by McDowall.

The relation between the fat and casein contents of normal milk, as expressed by the Van Slyke formula, has been useful for estimating factory efficiency.

When the exact quantity of casein in a given sample of milk must be known then the milk must be analyzed by a chemical method. The generality of a formula under such circumstance cannot be substituted for chemical procedures, as Hart (1908) pointed out in his work on variations in the amount of casein in cow's milk.

## REFERENCES

Anderson, A. C., (1914). Mich. Agr. Expt. Sta., Spec. Bul. 71.

Bartlett, S. (1935). J. Dairy Res., *6,* 283.

Dahlberg, A. C., Kucera, J. J., Hening, J. C. and Hucker, G. J., (1936). N. Y. (Geneva) Expt. Sta., Tech. Bul. 239.

Garrett, O. F., and Overman, O. R., (1940). J. Dairy Sci., *23,* 13.

Hart, E. B., (1908). J. Am. Chem. Soc., *30,* 281.

Jacobsen, Moses S., (1936). J. Dairy Sci., *19,* 171.

McDowall, F. H., (1936). N. Z. J. Sci. & Technol. *18,* 137.

Overman, O. R., (1945). J. Dairy Sci., *28,* 305.

Overman, O. R. and Garrett, O. F., (1932). J. Ag. Res., *45,* 51.

Overman, O. R., Garrett, O. F., Wright, K. E. and Sanmann, F. P., (1939). Ill. Agr. Expt. Sta., Bul. 457.

Perkins, A. E., Krauss, W. E. and Hayden, C. C., (1932). Ohio Agr. Expt. Sta., Wooster, Bul. 515.

Ragsdale, A. C. and Brody, S., (1922). J. Dairy Sci., *5,* 212.

Regen, W. M. and Richardson, G. A., (1938). J. Dairy Sci., *21,* 73.

Turner, C. W., (1936). Mo. Agr. Expt. Sta., Bul. 365.

Van Slyke, L. L., (1896). N. Y. (Geneva) Agr. Expt. Sta., Bul. 105. New series.

Van Slyke, L. L., (1908). J. Am. Chem. Soc., *30,* 1166.

## CHAPTER 3

# THE COMPOSITION AND QUALITY OF CHEDDAR CHEESE

The percentages of fat and solids-not-fat in milk are directly related to the composition of the finished cheese. Milk rich in fat normally produces cheese with more fat. The relation of composition to quality is not so easily demonstrated. But this relation between composition of milk and cheese and the quality of cheese requires some consideration at this point in our thinking.

### Composition of Cheddar Cheese

The normal manufacture of each variety of cheese follows definite procedures. These procedures are associated with losses of milk solids in the whey. These losses are characteristic of the variety of cheese and are relatively constant for the variety. These facts make it feasible to define cheese in terms of fat, solids-not-fat and moisture.

**Legal composition of cheese.** Cheese of the Cheddar variety is frequently called American or American Cheddar cheese when it is made in the United States. It may be called Canadian Cheddar or New Zealand Cheddar, and so on, when it is made elsewhere.

Cheddar cheese which is acceptable for interstate commerce in the United States is defined in the Federal Register (1941). The definition states in part that such cheese must contain not more than 39 per cent of moisture, and not less than 50 per cent of milk fat in the water-free substance. The definition states that the cheese may be made from milk from which part of the fat has been removed or to which has been added cream or skim milk.

Individual states, as well as the federal government, have laws or regulations that describe cheese in legal terms in order to protect the consumer against fraud and to promote honesty and fair dealing in commercial transactions.

**Normal composition of Cheddar cheese.** Cheese manufacturers regulate the composition of cheese within legal limitations to suit the purpose for which it is to be used. Cheese to be stored for a long period, for example, contains less moisture than that which is to be eaten while it is young and mild in flavor. Table 3:1 presents analyses of Cheddar cheese to show "average" compositions. The analyses reported by Van Slyke (1894b) show the composition of cheese produced in about 50 New York State factories during the making seasons of 1892 and 1893. These values are typical of the composition of Cheddar cheese commonly made today in most parts of the United States. The data from Hood and White (1930) and McDowall (1936) show analyses of products made in Canada and New Zealand, respectively. The lower moisture contents listed in columns (2) and (3) of the table probably reflect the demands of the English market.

TABLE 3:1. THE AVERAGE PERCENTAGE COMPOSITION OF CHEDDAR CHEESE

| *Source of data* | *(1)* *Van Slyke* *(1894b)* | *(2)* *Hood and White* *(1930)* | *(3)* *McDowall* *(1936)* |
|---|---|---|---|
| No. of observations | 150* | 444** | 785** |
| | % | % | % |
| Water | 36.84 | 34.82 | 34.90 |
| Total solids (dry matter) | 63.16 | 65.18 | 65.1 |
| Fat | 33.83 | 33.75 | 35.6 |
| Solids-not-fat (snf) | 29.33 | 31.43 | 29.5 |
| Casein | 23.72 | ... | ... |
| Salts, ash, etc. | 5.61 | ... | ... |
| Casein in dry matter | 37.55 | ... | ... |
| Fat in dry matter | 53.56 | 51.77 | 54.7 |
| Water as per cent of snf | 129.6 | 110.8 | 118.3 |

* Total number of days spent in factory observation during the seasons of 1892 and 1893; this is the minimum number of lots analyzed.

** Number of vats or lots of cheese.

**Percentage of fat in the dry matter.** It is customary for legal purposes to indicate the amount of fat in cheese as "percentage of fat in the dry matter." Table 3:1 shows average percentages of fat in the dry matter ranging from 51.77% in column (2) to 54.7 in column (3).

Higher percentages of fat in the milk tend to produce cheese with higher percentages of fat in the dry matter. The relationship is not exact. This is shown in figure 3:1. The points are

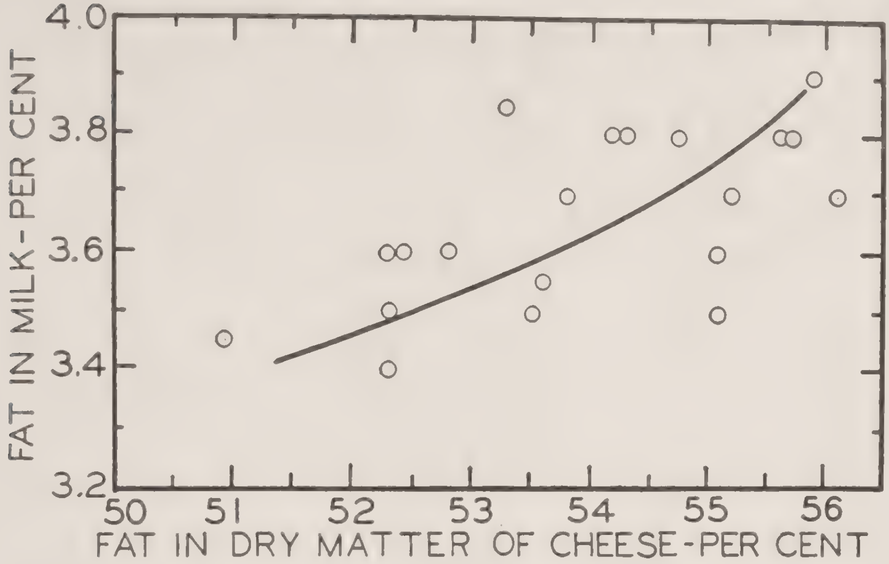


Figure 3:1. The relation between the fat in the milk and the fat in the dry matter of the cheese is subject to considerable variation. These data represent observations at a single factory for a period of 22 weeks. (*Van Slyke, 1894a*).

scattered and the relation is probably best represented by a curve. One is justified in concluding that the per cent of fat in milk cannot be used to predict accurately the percentage of fat in the dry matter of the cheese.

## Composition of Milk and Cheese

**Cheese solids.** The solids-not-fat in cheese are principally casein. The data in column (1) of table 3:1 show that 100 pounds of cheese averaged 63.16 pounds of dry matter of which 33.83 pounds were fat and 23.72 pounds were casein. Casein alone contributed 37.5% of the dry matter in the cheese. Fat and casein together constituted over 91% of the dry matter content of the cheese. These proportions indicate why the fat and casein of milk are known as "cheese solids."

**Casein/fat ratio.** The proportions of casein and fat in milk are commonly stated in terms of pounds of casein per pound of fat. This relation is important because it can be used to predict with a fair degree of accuracy the proportions of protein and fat, that is, pounds of protein per pound of fat, in the finished cheese. Data obtained in factory studies by Van Slyke (1894a) have been used to construct figure 3:2. The results indicate a straight line relation between the casein/fat ratio of the milk and the pounds of protein per pound of fat in the cheese. Milk with a casein/fat ratio of 0.60 produced cheese with a protein/fat ratio of approximately 0.65; when the casein/fat ratio was 0.70, the protein/fat was close to 0.73. The ratio of protein to fat was slightly higher in the cheese than in the milk. This can be explained by the normal loss of fat in the whey during the process of cheese making. In other kinds of cheese than Cheddar the relationship illustrated in figure 3:2 might be altered by differences in losses of fat and protein during the making operations.

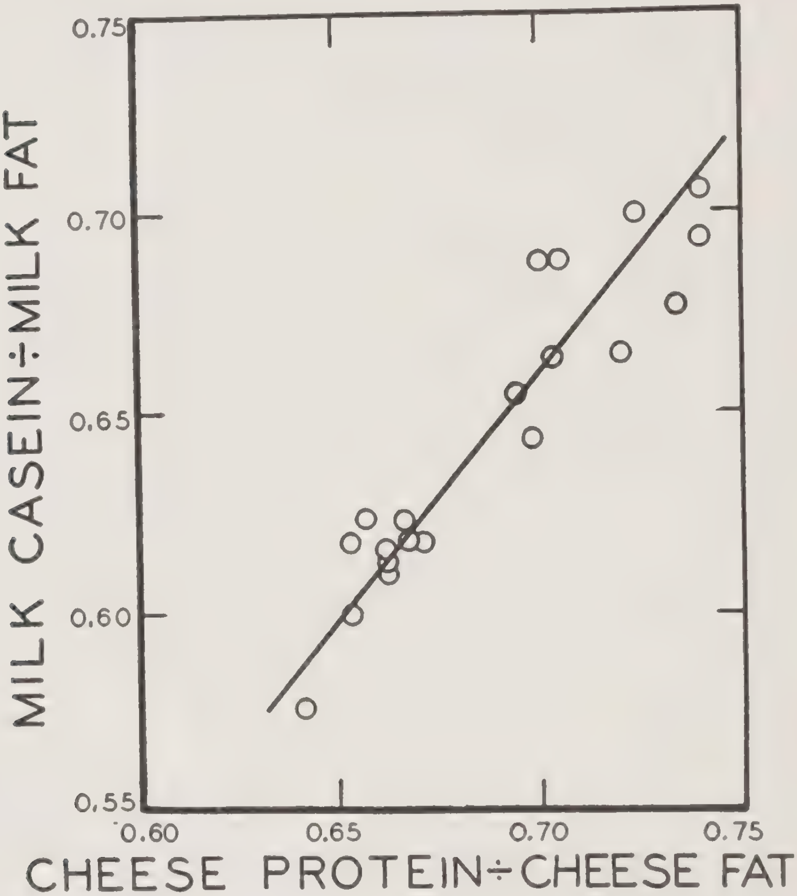


Figure 3:2. As the casein per unit of fat in the milk increases, so does the protein per unit of fat in the cheese. The trend of the relationship is shown by the line drawn by inspection to fit the observations. The data are from the work of Van Slyke *(1894a)*.

**Casein/fat ratio of milk and fat in cheese.** The close relation between the casein/fat ratio in milk and the protein/fat ratio in cheese illustrated in figure 3:2 suggests the principle of fat control that is widely used in careful manufacturing operations. Under factory conditions it is more practical to use the ratio of fat to dry matter than to use the ratio of protein to fat. This is partly because legal definitions are stated as percentages of fat in the dry matter. A second consideration is the fact that dry matter in cheese is more easily measured than protein. This dry matter includes fat, protein, milk salts, and the sodium chloride or common salt added to the curd during making. Dry matter, other than fat and protein, amounts to only about 9% of the total dry matter in the cheese and is not a highly variable factor in cheese composition.

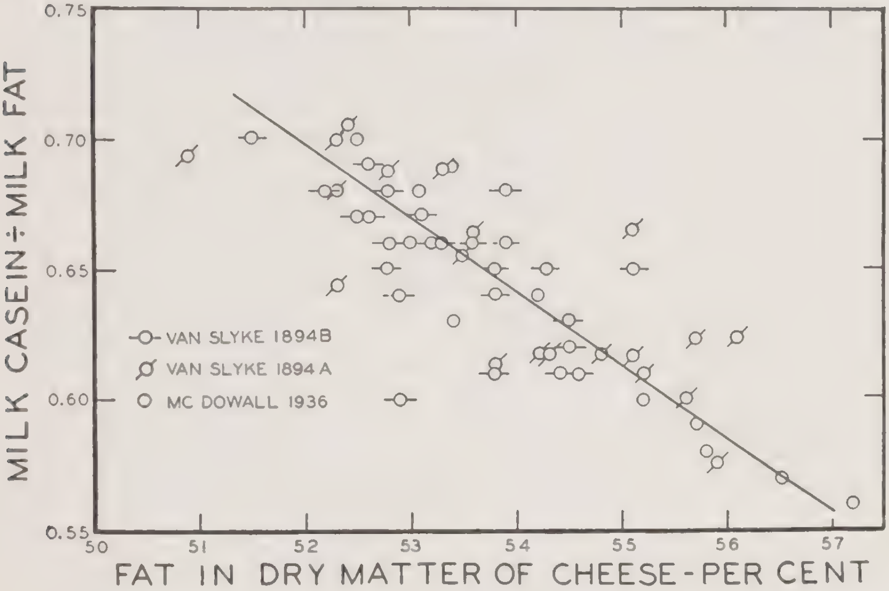


Figure 3:3. As the casein per unit of fat in the milk increases, the per cent of fat in the dry matter of the cheese decreases. The trend of the relationship is shown by the line drawn by inspection to fit the observations. The data are from three widely different sources.

Data from the records compiled by Van Slyke (1894a and 1894b) and McDowall (1936) have been used to develop figure 3:3. These data include the results of several seasons' work in New York State factories and approximately 150 vats of Cheddar cheese made in New Zealand. Different making procedures and equipment were used; the periods of the investigations and areas of manufacture were widely separated. But in spite of these differences the relationship between the casein/fat ratio in the milk and the percentage of fat in the dry matter of the cheese is surprisingly close in figure 3:3. The observations indicate that milk with a casein/fat ratio of 0.70 produced approximately 52% fat in the dry matter of the cheese; milk with a ratio of 0.60 gave cheese with close to 55%.

## COMPOSITION AND QUALITY OF CHEDDAR CHEESE

It is commonly agreed that the composition of cheese affects its quality. Anyone who has contrasted the eating qualities of whole milk Cheddar with those of tough, unpalatable, skim milk Cheddar never questions the influence of fat on body and flavor. Such comparisons are partly responsible for present legal definitions of cheese. These definitions tend to prevent indiscriminate cheapening of most varieties of cheese. It is interesting to study some of the available data on the composition and quality of cheese with some of these points in mind.

**Normal composition.** The data of table 3:1 show variations in composition of hundreds of lots of Cheddar cheese made at different times and in three different areas. Van Slyke had no grading records to accompany his data; he merely indicated that the cheese was of normal commercial quality. Hood and White included data on cheese in all commercial grades but more than half of these lots were Specials and First grade according to the Canadian system of grading. McDowall excluded abnormal cheese and cheese of questionable quality. It is probably safe to state that the cheese in all three groups were of satisfactory commercial quality or better. The averages of per cent of fat in the dry matter of the cheese in the three groups approximated 53% and showed a range of only 3%. The averages of water as per cent of solids-not-fat ranged from 110.8% to 129.6%. These may be tentatively regarded as normal values for Cheddar cheese of at least satisfactory quality.

TABLE 3:2. AVERAGE COMPOSITION OF DIFFERENT GRADES OF CANADIAN CHEDDAR CHEESE, 1925-1926
(Hood and White, 1930)

| *Grade* | *Number of samples* | *Moisture* | *Fat* | *Fat in water-free substance* |
|---|---|---|---|---|
| | | % | % | % |
| Special | 13 | 33.87 | 34.09 | 51.54 |
| First | 227 | 34.48 | 34.07 | 51.98 |
| Second | 162 | 35.29 | 33.34 | 51.53 |
| Third | 34 | 34.33 | 34.00 | 51.81 |
| No grade | 8 | 38.26 | 31.47 | 50.93 |

**Composition and quality of factory-made cheese.** Hood and White (1930) recorded the grades and composition of over 400 lots of Canadian Cheddar cheese. Their results are reproduced in part in table 3:2. They pointed out that the average composition for the different grades did not show much variation except for the samples placed in the no-grade group. The latter cheese, besides having serious flavor defects, were very weak and moist in body. Cheese in the Special and First grades contained from 30.75 to 38.84% water; that in the Second, Third, and no-grade classes ranged from 25.74 to 42.06% moisture. Average percentages of fat in the dry matter were practically identical in all grades.

Hood and White classified 375 of these lots of cheese which came under their observation and arranged them according to the judges' opinions of the body of the cheese. They then calculated the average composition of the cheese in each class. Their findings are presented in table 3:3. There was a definite increase in moisture and fat in the dry matter as the body varied from "too stiff" to "pasty." Solids-not-fat tended to decrease as body varied from stiff to pasty. Even in the classification of weakest body, the solids-not-fat averaged 29.73 while the fat in the water-free substance reached its maximum of 52.50%.

TABLE 3:3. RELATION BETWEEN THE COMPOSITION AND CONSISTENCY (BODY) OF CANADIAN CHEDDAR CHEESE
(Hood and White, 1930)

| *Body of cheese* | *No. of samples* | *Moisture* | *Fat* | *Fat in water-free substance* | *Solids-not-fat* |
|---|---|---|---|---|---|
| | | % | % | % | % |
| Too stiff | 42 | 31.44 | 34.74 | 50.65 | 33.82 |
| Slightly stiff, firm | 23 | 33.91 | 33.94 | 51.34 | 32.15 |
| Perfect | 42 | 34.30 | 33.86 | 51.55 | 31.84 |
| Good | 160 | 34.39 | 34.19 | 52.10 | 31.42 |
| Slightly weak | 32 | 36.62 | 32.90 | 51.90 | 30.48 |
| Weak, pasty | 76 | 37.40 | 32.87 | 52.50 | 29.73 |

## COMMERCIAL SIGNIFICANCE OF CHEESE COMPOSITION

Discussions of the relation between the composition and quality of cheese are usually limited to variations in fat and moisture contents. Legal definitions regulating these two factors are probably responsible for this emphasis. Such definitions protect the consumer against adulterations; they protect the industry against loss of prestige, such as occurred about 1880 when American cheese makers sent skim milk cheese and "filled" cheese to England; and they encourage efficient use of the cheese solids in milk. Actually the emphasis upon the influence of fat and moisture on quality may be somewhat misplaced. In commercial manufacturing operations the quality of cheese is more commonly endangered by the effects of lack of technical and bacteriological control of milk and cheese.

**Fat and quality.** Consumers do not discriminate against the cheese made in those seasons of the year when the fat content of the cheese is at its minimum. Neither do they choose the cheese made during those seasons when the fat content of the milk is naturally high. The experimental evidence gained by removing cream or skim milk from one portion of mixed milk and adding it to another identical portion is not too convincing. Such experiments may provide practically identical biological properties in the normal and modified milks but the modified milk is not normal in respect to the proportions of all milk constituents. There are good reasons to believe that the very process of centrifuging the milk to obtain the cream or skim milk for such adjustments actually alters the cheese-making properties of the milk. Such are some of the experimental difficulties which are encountered in studying the influence of variations in fat upon the quality of cheese which conforms in composition to legal requirements.

**Ratio of moisture to solids-not-fat.** The ratio of moisture to solids-not-fat in Cheddar cheese seems to be more closely related to quality than either fat or moisture alone. This may be explained by the fact that the amount of moisture retained in the curd affects the amounts of lactose and other water-soluble milk constituents in the cheese. The moisture has a direct effect on the speed and type of chemical and biological changes that occur in the protein during making and ripening. Solids-not-fat are mainly proteins in cheese. It is not surprising to find that as the ratio of moisture to solids-not-fat in Cheddar cheese becomes excessive the quality of the cheese is injured. Similar relations exist for other varieties of cheese but not in the proportions which seem to be critical for Cheddar cheese.

**Moisture and quality.** Moisture content has a decided influence on many properties of cheese such as: acidity, flavor, body, texture, and speed of ripening. These properties differ widely within each variety of cheese and for different types of cheese. Properties induced by low moisture are preferred by some consumers while buyers in other markets want cheese with high moisture. It is obvious that no single moisture standard can indicate a quality ideal for every market.

The moisture content of cheese is varied widely in commercial practice. Special treatments or procedures to control undesirable flavors or other defects are used during the manufacturing operations. Suitable allowances are made by the trade to protect the quality of the cheese during curing and merchandising. Such modifications and precautions, when they are successful, enhance the value of the cheese whether the moisture is "high" or "low" for that particular variety. Lack of such control of manufacturing and curing operations may lead to disastrous results even though the actual percentages of moisture may be well within the limits for the variety.

## REFERENCES

Federal Register (1941). Federal Register, *6*, 195.

Hood, E. G. and White, A. H. (1930). Dom. Can., Dept. of Agr., Bul. 79. New Series.

McDowall, F. H. (1936). New Zealand Jr. Sci. Technol., *18*, 137.

Van Slyke, L. L. (1894a). N. Y. (Geneva) Agr. Expt. Sta., Bul. 82. New Series.

Van Slyke, L. L. (1894b). N. Y. (Geneva) Agr. Expt. Sta., Bul. 65. New Series.

## CHAPTER 4

# STANDARDIZATION OF MILK FOR CHEESE

Standardization of milk for cheese making has for its purpose the regulation of the fat in the water-free portion, or dry matter of the cheese. Such adjustments make it possible to produce the greatest amount of cheese for each pound of fat in the milk that is used in making the cheese. The cheese made from such adjusted milk contains less fat than the cheese made from normal whole milk. Standardization decreases the total yield of cheese. Manufacturers must decide under what market conditions the increased revenue from cream sales is greater than the cost of the extra work and the loss in income from cheese sales.

**Legal requirements for cheese composition.** These requirements usually place a maximum limit on the moisture content of cheese. They commonly require that the fat must equal a certain percentage of the dry matter in the cheese. This simplifies legal definitions by making it unnecessary to state a minimum fat content for every variation in moisture.

**Federal regulations for Cheddar cheese.** The Federal Register (1941) contains the federal definitions of the Cheddar varieties of cheese. Cheddar, Washed-curd, and Colby cheese, according to these definitions, must contain not more than 39, 42, and 40% of moisture, respectively; these varieties must contain not less than 50% of fat in the dry matter. These federal definitions permit the manufacturer to adjust the composition of the milk to control the composition of the cheese, but they limit this adjustment to the removal of cream or the addition of skim milk. Laws of some states do not permit such adjustments of the milk for making cheese.

**Calculation of fat in the dry matter.** In order to calculate the percentage of fat in the dry matter it is necessary to know the percentage of fat and moisture in the cheese. For example: a cheese has 36% moisture and 32% fat. The dry matter content of the cheese is 64%; this is calculated by subtracting 36% from 100%. The percentage of fat in the dry matter is obtained by dividing the per cent of fat in the cheese, 32%, by the per cent of dry matter, 64%, and then multiplying the result by 100. For this cheese, the fat content is 50% of the dry matter (32% / 64% = 0.50; and 0.50 × 100 = 50%).

Table 4:1 shows percentages of fat in the dry matter corresponding to different amounts of fat and moisture in the cheese.

**Milk composition required for "legal" cheese.** Milk composition is commonly adjusted to some desired ratio of casein to fat (C/F) in order to control the amount of fat in the dry matter. A glance at figure 3:3 will show why a ratio of casein to fat is used. This figure shows that there is a close relation between the C/F ratio of the milk and the fat in the dry matter of Cheddar cheese. Although the relationship is significantly close, it is not exact; the per cent of fat in the dry matter varies over a range of approximately 3% for any given level of the C/F ratio. Thus, in figure 3:3, at C/F, 0.64, one vat lot contains 52.3% and another 54.8%. Standardization in a single factory from day to day should narrow this range but it is well to keep in mind that such variations are always possible. The C/F ratio in the milk should be adjusted so that the minimum fat content of the cheese will always be safely above that required by law. In the normal method of making Cheddar cheese a C/F ratio of 0.70 approximates the balance of casein and fat in the milk necessary to give the desired margin of safety. In factory practice, daily measurements of the composition of both milk and cheese will quickly indicate the desirability of using this or some other ratio. The ratio of C/F has the merit of establishing in the milk the same proportion of casein and fat that is normally found in milk with 3% of fat.

**Measuring weight and composition of milk.** Milk can be accurately standardized only when its weight and composition are known. In plant practice these facts are frequently known only approximately at the time of standardizing. Ideal conditions are provided in those plants where the milk can be weighed into storage tanks and then sampled for analysis before skimming operations begin.

Adjustments of composition can also be made in the cheese vat itself. After all the milk has been measured into the vat, a sample can be taken for analysis, the necessary calculations can be made and the amount of milk to be skimmed can be removed, separated, and the skim returned to the vat. The second method of adjustment can be made by placing a measured amount of skim milk of known composition in the cheese vat and then

## TABLE 4:1. PERCENTAGES OF FAT IN THE DRY MATTER CORRESPONDING TO DIFFERENT AMOUNTS OF FAT AND MOISTURE IN CHEESE

| *Moisture in cheese* | *Fat in cheese* | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *25%* | *26%* | *27%* | *28%* | *29%* | *30%* | *31%* | *32%* | *33%* | *34%* | *35%* | *36%* | *37%* | *38%* | *39%* | *40%* |
| % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % |
| 30 | 35.7 | 37.1 | 38.6 | 40.0 | 41.4 | 42.9 | 44.3 | 45.7 | 47.1 | 48.6 | 50.0 | 51.4 | 52.9 | 54.3 | 55.7 | 57.1 |
| 31 | 36.2 | 37.7 | 39.1 | 40.6 | 42.0 | 43.5 | 44.9 | 46.4 | 47.8 | 49.3 | 50.7 | 52.2 | 53.6 | 55.1 | 56.5 | 58.0 |
| 32 | 36.8 | 38.2 | 39.7 | 41.2 | 42.6 | 44.1 | 45.6 | 47.1 | 48.5 | 50.0 | 51.5 | 52.9 | 54.4 | 55.9 | 57.4 | 58.8 |
| 33 | 37.3 | 38.8 | 40.3 | 41.8 | 43.3 | 44.8 | 46.3 | 47.8 | 49.2 | 50.7 | 52.2 | 53.7 | 55.2 | 56.7 | 58.2 | 59.7 |
| 34 | 37.9 | 39.4 | 40.9 | 42.4 | 43.9 | 45.5 | 47.0 | 48.5 | 50.0 | 51.5 | 53.0 | 54.5 | 56.1 | 57.6 | 59.1 | 60.6 |
| 35 | 38.5 | 40.0 | 41.5 | 43.1 | 44.6 | 46.2 | 47.7 | 49.2 | 50.8 | 52.3 | 53.8 | 55.4 | 56.9 | 58.5 | 60.0 | 61.5 |
| 36 | 39.1 | 40.6 | 42.2 | 43.8 | 45.3 | 46.9 | 48.4 | 50.0 | 51.6 | 53.1 | 54.7 | 56.2 | 57.8 | 59.4 | 60.9 | 62.5 |
| 37 | 39.7 | 41.3 | 42.9 | 44.4 | 46.0 | 47.6 | 49.2 | 50.8 | 52.4 | 54.0 | 55.6 | 57.1 | 58.7 | 60.3 | 61.9 | 63.5 |
| 38 | 40.3 | 41.9 | 43.5 | 45.2 | 46.8 | 48.4 | 50.0 | 51.6 | 53.2 | 54.8 | 56.5 | 58.1 | 59.7 | 61.3 | 62.9 | 64.5 |
| 39 | 41.0 | 42.6 | 44.3 | 45.9 | 47.5 | 49.2 | 50.8 | 52.5 | 54.1 | 55.7 | 57.4 | 59.0 | 60.7 | 62.3 | 63.9 | 65.6 |
| 40 | 41.7 | 43.3 | 45.0 | 46.7 | 48.3 | 50.0 | 51.7 | 53.3 | 55.0 | 56.7 | 58.3 | 60.0 | 61.7 | 63.3 | 65.0 | 66.7 |
| 41 | 42.4 | 44.1 | 45.8 | 47.5 | 49.2 | 50.8 | 52.5 | 54.2 | 55.9 | 57.6 | 59.3 | 61.0 | 62.7 | 64.4 | 66.1 | 67.8 |
| 42 | 43.1 | 44.8 | 46.6 | 48.3 | 50.0 | 51.7 | 53.4 | 55.2 | 56.9 | 58.6 | 60.3 | 62.1 | 63.8 | 65.5 | 67.2 | 69.0 |
| 43 | 43.9 | 45.6 | 47.4 | 49.1 | 50.9 | 52.6 | 54.4 | 56.1 | 57.9 | 59.6 | 61.4 | 63.2 | 64.9 | 66.7 | 68.4 | 70.2 |
| 44 | 44.7 | 46.4 | 48.2 | 50.0 | 51.9 | 53.6 | 55.4 | 57.1 | 58.9 | 60.7 | 62.5 | 64.3 | 66.1 | 67.9 | 69.6 | 71.4 |
| 45 | 45.5 | 47.3 | 49.1 | 50.9 | 52.7 | 54.5 | 56.4 | 58.2 | 60.0 | 61.8 | 63.6 | 65.5 | 67.3 | 69.1 | 70.9 | 72.7 |

adding enough whole milk of known composition to give the correct balance of casein and fat. Both methods can be applied with equal accuracy providing the milk and skim milk can be accurately measured and analyzed.

Sometimes the quantity and composition of milk expected for the day's operations are estimated from records of milk received on preceding days. This procedure has the advantage of interfering less with plant routine and has the disadvantage of being the least accurate of the possible methods suggested. Milk composition and weight vary from day to day and from load to load of milk delivered during the day. When this estimating procedure is used, it is necessary to allow a margin of safety for these unpredictable variations. This is usually an inefficient practice and sometimes can be dangerously inaccurate.

**Measuring of fat and casein in milk.** When a representative sample of milk has been obtained, the fat content can be accurately determined by the usual Babcock test. Casein content of milk can be estimated from the fat content or can be measured by the Walker formol titration test. Other methods of analyzing milk for fat and casein are described in a publication of the Association of Official Agricultural Chemists (1945). These latter methods, in general, are not intended for use under cheese factory conditions where speed of operation is a fundamental consideration.

Probably the most practical method for measuring casein in factory practice is the rapid titration test described by Walker (1914) and modified by McDowall and Dolby (1936). It requires careful manipulation for dependable results and is not reliable in the hands of inexperienced operators.

**Estimating casein.** The casein content of normal, mixed milk can be estimated with fair accuracy by the formula

$$\text{Per cent Casein} = 0.4F + 0.9$$

In this formula F stands for per cent of fat in the milk. This method of estimating casein can be used for standardizing, but it should be employed only when analyses for fat in milk and for fat and moisture in cheese are made for each vat-lot of cheese. The casein/fat ratio in the milk can then be modified from day to day until the results are satisfactory.

Daily use of the fat test and lactometer to estimate the solids-not-fat content of vat-lots of whole milk will indicate milk of abnormal composition and will help to avoid gross errors in estimating casein.

## METHODS OF STANDARDIZING

The proper C/F ratio can be established in the milk to be made into cheese by three different procedures: (1) by adding skim milk; (2) by separating cream from the milk and restoring the skim milk to the remaining whole milk; and (3) by adding skim milk powder or concentrated skim milk to the milk. The last procedure is not permitted at present under the existing definitions of the Food and Drug Administration.

**Standardizing by adding skim milk.** This procedure is intended to add enough casein to establish the proper C/F ratio. It can best by illustrated by:

*Problem 4:1.* A factory operator desires to standardize 10,000 pounds of whole milk testing 4% fat and 2.5% casein so that the C/F ratio will be 0.70. He plans to use skim milk with 2.6% casein and 0.01% fat. How much skim milk will he have to add to the whole milk?

1) 10,000 × 4% = 400 pounds of fat in the whole milk.
   10,000 × 2.5% = 250 pounds of casein in the whole milk.
2) X (pounds of casein desired) : 400 (pounds fat) :: 0.70 : 1
   X = 400 × 0.70
   = 280 pounds casein desired.
3) 280 (pounds casein desired) — 250 (pounds casein in milk) = 30 pounds of casein needed in whole milk.
4) 30 (pounds casein needed) / 0.026 (pounds casein in one pound skim milk) = 1154 pounds skim milk required.

Proof of problem 4:1 is shown in table 4:2.

TABLE 4:2. PROOF OF STANDARDIZING CALCULATIONS FOR PROBLEM 4:1

| Product | Pounds | Fat | Casein | Fat | Casein |
|---|---|---|---|---|---|
| | | % | % | lb. | lb. |
| Whole milk | 10,000 | 4.0 | 2.5 | 400 | 250 |
| Skim milk | 1,154 | 0.01 | 2.6 | 0.1 | 30 |
| St'zed milk | 11,154 | | | 400.1 | 280 |

C/F = 280 / 400.1 = 0.70, the desired ratio.

**Standardizing by removing cream.** Two methods of calculating the amount of cream to remove for standardizing will be described. A formula is offered in the first method for those who find it convenient to use this type of expression of a series of calculations. The results of using this formula can only be as exact as the analyses and weights of which it is composed.

The second method which uses "Pearson's Square," is an arithmetical procedure which is based upon the assumption that casein always bears a constant relation to the amount of fat in the milk as expressed by the equation

$$\text{Per cent Casein} = 0.4\text{F} + 0.9.$$

It has already been indicated that determination of the composition of the cheese should always be used to guide subsequent standardizing operations. This is particularly important when the amount of casein in the milk is estimated from its fat content.

*Formula Method.* The following formula has been developed to provide a routine method for calculating the amount of cream to separate from a given quantity of milk of known composition

$$\text{Pounds of cream} = \frac{\text{M (rf} - \text{c)}}{\text{rs} - \text{t}}$$

M = the pounds of whole milk to be standardized
r = the C/F ratio desired in the standardized milk
f = pounds of fat in one pound of whole milk
c = pounds of casein in one pound of whole milk
s = pounds of fat in one pound of cream
t = pounds of casein in one pound of cream

The application of this formula is illustrated by:

*Problem 4:2.* Whole milk weighing 10,000 pounds and containing 4% fat and 2.5% casein is to be standardized to a C/F ratio of 0.70. The cream to be separated is expected to contain 40% fat and 1.6% casein. How much cream must be removed if all the skim milk is returned to the remaining whole milk?

(1) Substituting the above values in the formula we have:

$$\begin{aligned}
\text{Pounds of cream} &= \frac{10{,}000\ [(0.70 \times 0.04) - 0.025]}{(0.70 \times 0.40) - 0.016} \\
&= \frac{10{,}000\ (0.028 - 0.025)}{0.28 - 0.016} \\
&= \frac{10{,}000 \times 0.003}{0.264} \\
&= \frac{30}{0.264} \\
&= 113.5
\end{aligned}$$

Proof of this solution of Problem 4:2 is shown in table 4:3.

TABLE 4:3. PROOF OF STANDARDIZING CALCULATIONS FOR PROBLEM 4:2

| *Product* | *Pounds* | *Fat* | *Casein* | *Fat* | *Casein* |
|---|---|---|---|---|---|
| | | % | % | lb. | lb. |
| Whole milk | 10,000 | 4.0 | 2.5 | 400.0 | 250.0 |
| Cream | 113.5 | 40.0 | 1.6 | 45.4 | 1.8 |
| St'zed milk | 9,886.5 | | | 354.6 | 248.2 |

C/F = 248.2 / 354.6 = 0.70, the desired ratio.

*"Pearson's Square" Method.* Pearson's square can be used in standardizing milk for cheese. Table 4:4 has been developed to simplify these calculations. It shows the percentage of fat required in the standardized milk to balance casein contents from 2.0% to 3.0% when desired C/F ratios range from 0.70 to 0.75.

TABLE 4:4. PER CENT FAT REQUIRED IN STANDARDIZED MILK TO GIVE DESIRED RATIO OF C/F IN STANDARDIZED MILK

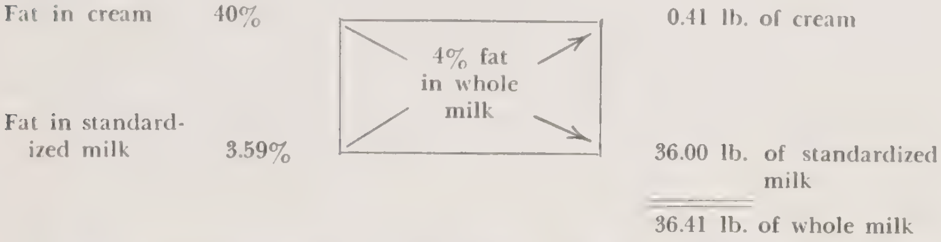
| *Per cent casein in whole milk* | *Per cent fat in standardized milk when desired C/F ratio is:* | | | | | |
|---|---|---|---|---|---|---|
| | .70 | .71 | .72 | .73 | .74 | .75 |
| % | % | % | % | % | % | % |
| 2.0 | 2.87 | 2.83 | 2.80 | 2.76 | 2.72 | 2.69 |
| 2.1 | 3.02 | 2.97 | 2.94 | 2.90 | 2.86 | 2.82 |
| 2.2 | 3.16 | 3.12 | 3.08 | 3.03 | 3.00 | 2.96 |
| 2.3 | 3.30 | 3.26 | 3.22 | 3.17 | 3.13 | 3.09 |
| 2.4 | 3.45 | 3.40 | 3.36 | 3.31 | 3.27 | 3.23 |
| 2.5 | 3.59 | 3.54 | 3.50 | 3.45 | 3.41 | 3.36 |
| 2.6 | 3.74 | 3.68 | 3.64 | 3.59 | 3.54 | 3.49 |
| 2.7 | 3.88 | 3.82 | 3.78 | 3.72 | 3.68 | 3.63 |
| 2.8 | 4.02 | 3.97 | 3.92 | 3.86 | 3.81 | 3.76 |
| 2.9 | 4.17 | 4.11 | 4.06 | 4.00 | 3.95 | 3.90 |
| 3.0 | 4.31 | 4.25 | 4.20 | 4.14 | 4.09 | 4.03 |

The idea involved in standardizing with Pearson's square is to determine the amount of cream and standardized milk that can be obtained from the whole milk. The manner in which the "square" is used suggests that the cream and standardized milk are being combined to form the whole milk. The method can be illustrated by:

*Problem 4:3.* Whole milk weighing 10,000 pounds and containing 4% fat and 2.5% casein is to be adjusted to a C/F ratio of 0.70. The cream to be separated will contain 40% fat and 1.6% casein. All the skim milk will be returned to the remaining milk. How much cream must be removed?

(1) In table 4:4 the per cent of fat required to balance the 2.5% casein at the C/F ratio of 0.70 is 3.59%

(2) Pearson's square is set up as follows:



(3) The proportioning of the combination of cream and standardized milk indicated by the square can now be used to calculate the pounds of cream to separate:

$$\text{Pounds of cream} : 0.41 :: 10{,}000 : 36.41$$
$$\text{Pounds of cream} = 0.41 \times 10{,}000/36.41$$
$$\doteq 112.6 \text{ pounds of } 40\% \text{ cream to separate.}$$

Proof this solution of Problem 4:3 is shown in table 4:5.

TABLE 4:5. PROOF OF STANDARDIZING CALCULATIONS FOR PROBLEM 4:3

| *Product* | *Pounds* | *Fat* | *Casein* | *Fat* | *Casein* |
|---|---|---|---|---|---|
| | | % | % | lb. | lb. |
| Whole milk | 10,000 | 4.0 | 2.5 | 400.0 | 250.0 |
| Cream | 112.6 | 40.0 | 1.6 | 45.0 | 1.8 |
| St'zed milk | 9,887.4 | | | 355.0 | 248.2 |

C/F = 248.2 / 355 = 0.70, the desired ratio.

**Variations in expected per cent of fat in cream.** When the per cent of fat in the cream delivered by the separator varies significantly from the percentage expected, it is necessary to make some adjustment in the standardizing operation.

If the cream is richer in fat than expected, then too much fat will have been removed. One way of making the necessary correction is to recalculate the amount of cream to remove using the actual fat test of the rich cream. The second method is to standardize the rich cream with milk from the cheese vat to obtain the percentage of fat that was expected when the original calculations were made. Regardless of the method used, it will be necessary to restore the excess cream to the cheese vat. Every effort should be made to mix it thoroughly with the milk in the vat.

If the cream contains less fat than was expected, the operator may choose to recalculate his standardizing operation and then continue to separate until sufficient fat has been removed. Some operators might choose to reseparate the thin cream and then standardize it with milk to the percentage of fat used in making the original calculations.

**Estimation of pounds of milk to separate.** It may be easier in plant practice to account for the quantity of milk separated rather than the amount of cream to remove. This may be particularly true when the fat content of the cream tends to vary widely from day to day. When it is desirable to estimate the pounds of milk to separate, the calculations can be based upon the procedures which have been described. In the proof of the standardizing calculations of table 4:3 the amount of fat to be removed in the cream is 45.4 pounds. Since the milk to be separated contains 4% fat, each pound of milk contributes 0.04 pounds of fat. In order to remove 45.4 pounds of fat from this milk, it will be necessary to skim 1135 pounds of milk (45.4/0.04 = 1135). For practical purposes and ease of calculation it is preferable to ignore the fraction of a pound of fat which remains in the skim milk.

**Accuracy of control of fat in cheese by standardization.** Standardization of milk does not guarantee absolute uniformity of cheese composition. Variations can be caused by several factors.

Price and Germain (1931) standardized milk to a casein/fat ratio of 0.7. Their analyses of 36 lots of cheese showed an average of 51.9% fat in the dry matter with a probable error for the series of ± 0.15%. They stated: "It is clearly evident that the establishment of a casein to fat ratio of 0.7 is low enough to guarantee at least 50 per cent of fat in the dry matter of the cheese. The average fat content of the dry matter of the standardized cheese is nearly 2 per cent over the minimum required by law. It is possible to reduce this difference between the legal requirement and the actual fat content of the cheese. It would require careful manipulation of tests and calculations to accomplish such results without risk of making illegal cheese. The manipulations in the laboratory resulted in the production of four lots of cheese which contained between 50 and 50.5 per cent fat in the dry matter. The limits of accuracy of the methods of analysis, which are available for use in cheese factories at the present time, would probably discourage attempts to make cheese conform more closely to the minimum requirements."

McDowall (1936) reported analyses of 202 vats of milk which had been standardized to a casein/fat ratio of 0.7. Three lots contained between 50% and 50.5% fat in the dry matter while two lots had 54% to 54.5%; the average for the 202 vats was 52.5%. All lots contained 50% or more fat in the dry matter. The standardizing operations of Price and Germain and those of McDowall were based upon the use of the Walker casein test to measure the amounts of casein in the milk. McDowall's data have been used to construct figure 4:1 which shows the distribution of his analyses according to percentages of fat in the dry matter of the cheese.

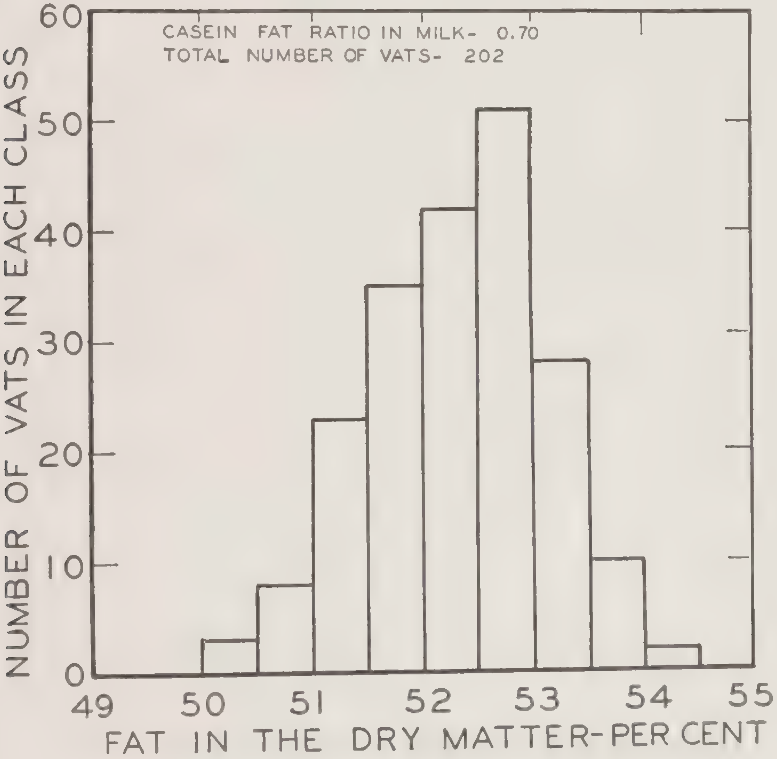


Figure 4:1. This diagram shows the distribution of numbers of vat lots of cheese according to their content of fat in the dry matter. All vat lots were made from milk with a casein/fat ratio of 0.70. The original data are those of McDowall *(1936)*.

**Reasons for variations from expected fat content.** Variations of actual percentages of fat in the dry matter from the amounts expected can be explained by any one of several reasons, or by combinations of them.

(1) Wrong analyses for fat, or casein, or both, may be responsible. Estimates of casein calculated from the per cent of fat in the milk may differ by as much as 0.3% from analytical measurements. This type of deviation is frequently observed on cold days of fall and early winter.

(2) Errors in calculating amounts of cream to remove, or skim milk to add, can be responsible for variations. In factory practice there is constant pressure to act quickly in order to get the making process under way. Calculations should always be checked. Records of standardizing procedures compiled day after day soon became adequate to detect gross errors in calculations.

(3) Inaccuracies in measuring quantities of milk, cream, and skim milk by volume are common causes of variations. Frequently, separation of milk may begin before all of the milk has been received. Obviously, composition as well as quantities must then be estimated. There is a growing tendency to install large holding tanks in factories. These tanks simplify the standardizing problem and make possible more accurate control of cheese composition.

(4) Occasionally equipment failures or carelessness of labor result in lack of control of cheese composition. Equipment failures can sometimes be avoided by proper maintenance and prompt servicing of machinery in need of repairs. Failures of labor may be prevented by proper time allowances for execution of necessary operations, by careful supervision, by using the most skillful individual for standardizing operations, or by combinations of these precautions.

(5) Unusual losses of milk solids in the whey can nullify the most careful standardizing procedures. Such losses can be caused by abnormal milk, milk of inferior quality, lack of acidity control, and careless or thoughtless manufacturing procedures. Abnormal milk can influence curd formation unfavorably. Inferior milk may develop uncontrolled fermentations and cause excessive losses of fat or protein, or both. Lack of acid control will influence the drainage of whey from the curd and so affect the balance of fat and solids-not-fat in the cheese. Careless handling of the curd, such as breakage, lack of temperature control, excessive use of hot water on the curd, and careless salting opera

tions, all may result in unusual variations in cheese composition.

**Checking results of standardizing.** Cheese made from standardized milk should always be analyzed for fat and moisture before it is sold. Such analyses are essential to avoid the possible repetition of errors in controlling the percentage of fat in the dry matter of the cheese. These analyses indicate trends of daily and seasonal changes in milk that affect the retention of fat and solids-not-fat in the cheese. They provide data which show from day to day whether the operator is experiencing difficulty in control and what corrections are needed, if any. They finally provide an accurate record of vat-lots of cheese which may eventually be sampled and analyzed by law enforcement officials. Checking the results of standardizing operations by analyzing the finished cheese is as essential as the initial analyses of the milk itself.

## EFFECTS OF STANDARDIZING MILK FOR CHEDDAR CHEESE

Van Slyke (1897) pointed out that fat in high-testing milk would be more efficiently utilized if skim milk were added. He believed, however, that such a practice would cause deterioration of cheese quality. Klueter (1928) observed no ill effect on quality after he had made cheese from standardized milk at two factories.

Sammis and Germain (1929) studied experimentally the influence of the proportions of moisture and fat on cheese quality. They removed more or less cream or skim milk from various portions of identical milk. The mixtures were then made into cheese with as close to 39% moisture as was possible to obtain. Table 4:6 summarizes some of their data.

The high moisture content desired in the cheese was attained in all groups of cheese in table 4:6 excepting Group 6 which

TABLE 4:6. THE RELATIONSHIP BETWEEN COMPOSITION AND QUALITY OF CHEDDAR CHEESE

(Sammis and Germain, 1929)

| *Group no.* | *Number of lots* | *Number of sour lots* | *Water / SNF* | *Fat in dry matter* | *Average score* |
|---|---|---|---|---|---|
| | | | lb. | % | |
| 1 | 9 | 9 | 1.66 | 59.3 | 78.7 |
| 2 | 10 | 5 | 1.55 | 59.0 | 81.4 |
| 3 | 16 | 5 | 1.45 | 56.9 | 83.9 |
| 4 | 17 | 2 | 1.32 | 51.7 | 85.1 |
| 5 | 14 | 1 | 1.27 | 50.5 | 86.2 |
| 6 | 13 | 0 | 1.19 | 52.1 | 88.2 |

LIBRARY

contained 36.3%. The ratio of moisture to solids-not-fat in the cheese was regarded as of primary importance by these workers. This ratio, stated as pounds of water per pound of solids-not-fat, decreased as the average score of the cheese increased. The higher proportions of moisture to solids-not-fat in the cheese produced sour cheese. This effect more than counter-balanced the possible desirable influence of the increased amounts of fat in the dry matter of the cheese. The ratios of water to solids-not-fat in all but two of these groups of experimental cheese were considerably above the normal values found in Cheddar cheese. The extreme variations of milk and cheese solids established in these experiments probably would not be found in practice, but the trends of their influence on quality must be regarded as significant.

Hansen and Theophilus (1930) added dry skim milk to whole milk to increase the proportion of solids-not-fat to fat (SNF/Fat) in whole milk. They used milk containing an average of 3.6% fat and 2.38 pounds of solids-not-fat per pound of fat. They added the dry skim milk to three portions of this milk so that the portions contained 2.6, 2.8, and 3.0 pounds of solids-not-fat per pound of fat. The milks with these three ratios of SNF/Fat, when made into cheese, produced 54.29%, 52.54%, and 49.73% fat in the dry matter, respectively. The control lots of milk gave cheese with an average of 57.22% fat in the dry matter. Fat losses in the whey tended to decrease slightly with increased ratios of SNF/Fat. The scores of the cheese showed that the standardization of the milk with dry skim milk had no appreciable influence upon the quality of the finished cheese.

Price and Germain (1931) studied the control of milk composition and the relation between the composition of milk and the composition and quality of Cheddar cheese. They removed enough cream from whole milk to establish a ratio of 0.7 pounds of casein for one pound of fat in the milk. The significant statistics are summarized in table 4:7. The data in this table show that standardization of milk to a casein-fat ratio of 0.7 had the effect of utilizing the fat more efficiently without significant change in cheese quality. This efficiency was more apparent when the whole milk contained more than 3.5% fat. They observed only a slight tendency toward improved quality with increasing amounts of dry matter and fat in the cheese. They noted a definite improvement in quality with decreasing amounts of moisture per pound of solids-not-fat in the cheese.

Doane (1940), after many years of practical observations of the effects of modifying the fat content of milk, stated that the practice was not injurious when properly done.

TABLE 4:7. EFFECTS OF STANDARDIZING BY REMOVING CREAM FROM MILK

(Price and Germain, 1931)

| *Treatment* | *Not Standardized* | *Standardized* |
|---|---|---|
| No. of vats | 36 | 36 |
| Milk: | | |
| Fat | 3.92 % | 3.56 % |
| Casein | 2.47 % | 2.48 % |
| Casein per 1 lb. fat | 0.63 lb. | 0.697 lb. |
| Whey: | | |
| Fat | 0.27 % | 0.25 % |
| Solids-not-fat | 6.57 % | 6.50 % |
| Cream, 40%: | | |
| Amount removed | none | 1.02 lb. |
| Cheese: | | |
| Moisture | 35.5 % | 36.0 % |
| Fat | 34.8 % | 33.2 % |
| Fat in dry matter | 54.0 % | 51.9 % |
| Yield: | | |
| Cheese per 100 lb. milk | 10.09 lb. | 9.69 lb. |
| Cheese per 1 lb. fat in milk | 2.57 lb. | 2.72 lb. |
| Score: | | |
| Flavor superiority | 0.1 | — |
| Body and texture superiority | 0.1 | — |
| Total score superiority | 0.2 | — |

Arbuckle (1943) found that a ratio of one pound of fat to 3.3 pounds of solids-not-fat in milk gave most satisfactory results in standardizing. He observed that the yield of cheese from 100 pounds of milk was decreased by standardizing, but the yield of cheese per pound of fat was increased. Standardization had no appreciable effect upon the quality of the cured cheese; a slight stiffness of body, sometimes observed in the fresh cheese, disappeared in aging.

## REFERENCES

Arbuckle, W. S. (1943). Southern Dairy Products J., *33*, No. 6:12.

Association of Official Agricultural Chemists (1945). Official and Tentative Methods of Analysis. p. 308. Washington, D. C.

Doane, C. F. (1940). Nat. Butter & Cheese J., *31*, No. 6:36.

Federal Register (1941). Federal Register, *6*, 195.

Hansen, H. C. and Theophilus, D. R. (1930). Idaho Agr. Expt. Sta., Bul. 174.

Klueter, H. (1928). Report of the Dairy and Food Commission of Wisconsin, 1927-1928, p. 76.

McDowall, F. H. (1936). New Zealand J. Sci. Technol., *18,* 137.

McDowall, F. H. and Dolby, R. M. (1936). New Zealand J. Sci. Technol., *17,* 619.

Price, W. V. and Germain, Leo (1931). Wis. Agr. Expt. Sta., Res. Bul. 108.

Sammis, J. L. and Germain, Leo (1929). Butter & Cheese J., *20,* No. 18:13.

Van Slyke, L. L. (1897). N. Y. (Geneva) Agr. Expt. Sta., 15th Annual Report, p. 93.

Walker, W. O. (1914). J. Ind. & Eng. Chem., *6,* 131.

## CHAPTER 5

# MILK CONSTITUENTS AND THE YIELD OF CHEESE

The amount of cheese obtained from milk is an indication of the efficiency of the cheese making operations. The yield of cheese is affected by such conditions as the quality of the milk, the nature of the manufacturing operations, the skill of the maker, and, finally, the curing procedures.

Two methods of stating yield are commonly used. One gives the pounds of cheese made from 100 pounds of milk; this is sometimes called the percentage yield. The other states the pounds of cheese made for each pound of fat in the original milk. The pounds of milk required to make a pound of cheese are frequently included in factory statements but such a relation is more a measure of factory efficiency in the utilization of milk rather than a statement of cheese yield.

**Conditions determining the yield of cheese.** The amount of fresh or unripened cheese obtainable from 100 pounds of milk depends upon four factors: 1) the composition of the milk; 2) the amounts of milk constituents lost in the whey; 3) the amount of salt added in the making process; and 4) the amount of water retained in the cheese.

These factors determine the amount of any kind of cheese that can be obtained from a known quantity of milk. The discussion in this chapter, however, is limited to Cheddar cheese, the variety studied by investigators when these relationships were first developed by experimental methods and factory observations.

**Changing milk into curd and whey.** The first irrevocable step in cheese making is the coagulation of the milk. Casein is the milk constituent that forms the gel or coagulum. This casein gel, or curd as it is commonly called, holds mechanically a large proportion of those constituents of milk that are insoluble or in suspension; such constituents include milk fat and insoluble phosphates. It holds chemically the calcium with which it is normally combined. Dispersed throughout this gel are the other milk constituents consisting of water and those substances that are water soluble. They are held in curd much as water is held in a sponge. The curd contracts as the cheese-making process progresses and the water and the materials dissolved in it are partially expelled as whey. Just as a sponge retains some of its water when it is squeezed, so the curd retains a portion of its whey at the end of the cheese-making process. So it is apparent that the yield of cheese must be related directly to the composition of the milk from which it is made. To what extent this is true will be made clear by considering data from actual cheese-making operations.

**Data from factory operations.** Actual cheese factory operations were studied in New York in the years 1892 and 1893 to learn more about the constituents of milk in the manufacture of cheese (Van Slyke 1894b). During these years a total of 150 days of factory observations, records, and analyses were accumulated. During these days a total of 939,427 pounds of milk were made into 94,192 pounds of cheese. The information provided by these studies can be used to explain some of the relationships between milk constituents, cheese yields, and finally the value of milk to be used for cheesemaking.

The composition of the milk averaged by months for the two seasons of work is shown in table 5:1. These data show a normal upward trend in milk solids from spring to fall. This trend is characteristic of herds which freshen in the spring. During one season severe drought conditions prevailed in July and August. The solids content of the milk dropped. This effect can be seen

TABLE 5:1. THE AVERAGE PERCENTAGE COMPOSITION OF MILK MADE INTO CHEDDAR CHEESE DURING TWO SEASONS
(Van Slyke, 1894b)

| *Month* | *Total solids* | *Fat* | *Casein* | *Albumin* | *Sugar, ash, etc.* |
|---|---|---|---|---|---|
| | % | % | % | % | % |
| April | 11.98 | 3.43 | 2.29 | 0.52 | 5.74 |
| May | 12.43 | 3.58 | 2.34 | 0.68 | 5.83 |
| June | 12.64 | 3.64 | 2.47 | 0.77 | 5.76 |
| July | 12.52 | 3.62 | 2.43 | 0.64 | 5.83 |
| Aug. | 12.65 | 3.84 | 2.39 | 0.61 | 5.79 |
| Sep. | 12.86 | 3.98 | 2.55 | 0.65 | 5.68 |
| Oct. | 13.50 | 4.23 | 2.81 | 0.74 | 5.73 |
| Average for two seasons | 12.67 | 3.75 | 2.46 | 0.68 | 5.78 |

in the averages for the two seasons of observations included in the data.

**Distribution of milk constituents in whey and cheese.** The general nature of a normal distribution of milk constituents in making Cheddar cheese is diagrammed in figure 5:1. A little fat and casein appear in the whey as unavoidable losses. A small portion of milk sugar and albumin remain in the fresh cheese.

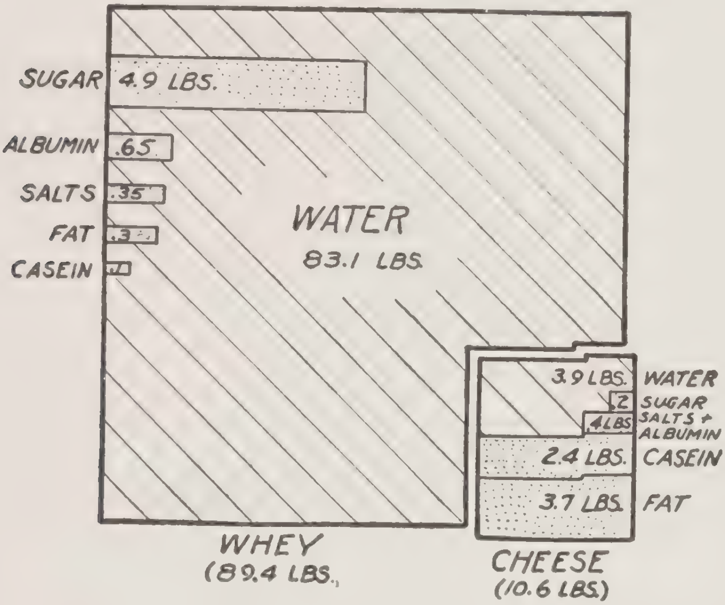


Figure 5:1. The division of milk constituents when 100 pounds of milk containing 4 per cent fat is made into Cheddar cheese.

Table 5:2 shows the distribution of milk solids between whey and cheese as observed in two seasons of factory practice (Van Slyke, 1894b). Approximately one half of the milk solids were recovered in the cheese, the remainder went into the whey. The proportion of milk solids retained in the cheese ranged from 45.27% to 56.43% of the original dry matter content of the milk and averaged 50.52%. The solids recovered increased with the seasonal upward trend of total solids in the milk. The increase in percentage of solids recovered can be attributed to the greater proportions of fat and casein normally found in milk of higher solids content. The milk solids in the whey from 100 pounds of milk varied from 5.81 to 6.83 pounds and averaged 6.25 pounds. Milk solids recovered in the cheese from 100 pounds of milk ranged from 5.31 to 7.58 pounds and averaged 6.38 pounds. This division of milk solids indicates why efficient manufacturers

TABLE 5:2. THE AVERAGE DISTRIBUTION OF MILK SOLIDS BETWEEN WHEY AND CHEESE AT CHEDDAR CHEESE FACTORIES

(Van Slyke, 1894b)

| *Month* | *Total solids in 100 pounds of milk* | *Total solids in whey* | *Total solids in cheese* | *Percentage distribution of total solids* | |
|---|---|---|---|---|---|
| | | | | *Whey* | *Cheese* |
| | lb. | lb. | lb. | % | % |
| April | 11.98 | 6.19 | 5.79 | 51.7 | 48.3 |
| May | 12.43 | 6.35 | 6.08 | 51.1 | 48.9 |
| June | 12.64 | 6.31 | 6.33 | 49.9 | 50.1 |
| July | 12.52 | 6.26 | 6.26 | 50.0 | 50.0 |
| Aug. | 12.65 | 6.21 | 6.44 | 49.1 | 50.9 |
| Sep. | 12.86 | 6.11 | 6.75 | 47.5 | 52.5 |
| Oct. | 13.50 | 6.14 | 7.36 | 45.4 | 54.6 |
| Average for two seasons | 12.67 | 6.25 | 6.38 | 49.5 | 50.5 |

are making every effort to conserve whey for food. Most whey is still being returned to the farms for stock food either in liquid or dried forms. More and more of it will probably be used as human food as methods of manufacture and methods of utilization are developed.

**Composition of whey.** The composition of whey varies according to the composition of the milk from which it comes, and according to the variations in losses of milk solids during the process of making the cheese. Milk with relatively large amounts

TABLE 5:3. THE AVERAGE COMPOSITION OF WHEY AT CHEDDAR CHEESE FACTORIES

(Van Slyke, 1894b)

| *Month* | *Water* | *Total solids* | *Fat* | *Protein ** | *Sugar, salts, etc.* |
|---|---|---|---|---|---|
| | % | % | % | % | % |
| April | 93.17 | 6.83 | 0.40 | 0.73 | 5.70 |
| May | 92.98 | 7.02 | 0.38 | 0.81 | 5.83 |
| June | 92.99 | 7.01 | 0.31 | 0.88 | 5.82 |
| July | 93.05 | 6.95 | 0.35 | 0.83 | 5.77 |
| Aug. | 93.08 | 6.92 | 0.38 | 0.80 | 5.74 |
| Sep. | 93.18 | 6.82 | 0.41 | 0.85 | 5.56 |
| Oct. | 93.04 | 6.96 | 0.38 | 0.98 | 5.60 |
| Average for two seasons | 93.04 | 6.96 | 0.36 | 0.84 | 5.76 |

* Proteins in whey are almost entirely albumin.

of soluble constituents produces whey which is relatively rich in these substances. Handling procedures which tend to destroy normal curd formation increase the solids content of the whey. Increasing acidity during making tends to decrease the lactose content of the whey but increases the amounts of soluble calcium released in the whey.

Table 5:3 shows the average percentage composition of whey observed in the factories making Cheddar cheese. This whey was sampled for analysis at the time it was removed from the curd. The average values from month to month for all constituents of the whey were remarkably uniform. This might be expected because the data include a large number of observations obtained during the two making seasons.

The minimum pounds of fat lost in the whey from 100 pounds of milk was 0.21 and the maximum, 0.50 pounds. The average of all observations during the two making seasons was 0.33 pounds, equivalent to 8.87% of the fat in the original milk.

The facts indicate that the proportion of milk fat lost in the whey does not depend primarily on the fat content of the milk, but rather upon the condition of the milk, or the methods of manufacture, or both.

**Losses of protein in whey.** Table 5:3 shows the losses of protein experienced in the factories under observation. These losses ranged from 0.58 to 0.91 pounds and averaged 0.76 pounds in the whey from 100 pounds of milk. Losses were lowest in April and highest in October because proteins in whey are almost entirely albumin.

In general the proportion of the proteins lost in whey approximates 25% of the proteins in the milk. It depends primarily upon the albumin content of the milk used in the cheese-making process and, to a lesser degree than fat losses, upon the condition of the milk and the methods of manufacture.

**Losses of casein in whey.** The amount of casein in whey from Cheddar cheese is normally very small. When milk is inferior in quality, or when the curd is unskillfully handled, then the losses of casein are increased. Some small particles of curd, too fine for the usual strainers to retain, always escape into the whey. They readily settle out of whey which is allowed to stand without agitation. They are thrown to the sides of the whey separator bowl and, if present in excessive amounts, will decrease the efficiency of fat recovery. These curd particles contain higher proportions of protein and lower proportions of fat than the normal curd. It is possible that the enzyme, rennin, may release a soluble fraction of the casein molecule when milk is coagulated, but this fraction must be less than 0.1 per cent of the whey.

The amount of casein found in the whey during the factory studies under consideration varied from 0.04 to 0.16 pounds and averaged 0.09 pounds in 100 pounds of whey.

TABLE 5:4. AVERAGE AMOUNTS OF FAT, PROTEINS, AND WATER RECOVERED IN CHEDDAR CHEESE MADE FROM 100 POUNDS OF MILK
(Van Slyke, 1894b)

| *Month* | *Recovery of fat ** | | *Recovery of proteins ** | | *Water* |
|---|---|---|---|---|---|
| | lb. | % | lb. | % | lb. |
| April | 3.07 | 89.5 | 2.15 | 76.5 | 3.56 |
| May | 3.23 | 90.2 | 2.28 | 75.5 | 3.58 |
| June | 3.35 | 92.3 | 2.44 | 75.5 | 3.59 |
| July | 3.31 | 91.2 | 2.32 | 75.8 | 3.58 |
| Aug. | 3.50 | 91.2 | 2.30 | 76.2 | 3.72 |
| Sep. | 3.55 | 90.6 | 2.41 | 76.0 | 3.77 |
| Oct. | 3.87 | 92.1 | 2.73 | 75.4 | 4.51 |
| Average for two seasons | 3.39 | 91.1 | 2.37 | 75.7 | 3.72 |

$$\text{* Percentage recovery} = \frac{\text{Pounds of fat (or proteins) in cheese} \times 100}{\text{Pounds of fat (or proteins) in milk}}$$

**Recovery of milk solids in cheese.** Table 5:4 summarizes data from the Cheddar factories showing the amounts of total solids, fat, proteins, and water retained in the cheese. It is unnecessary to discuss reasons for trends in the data in this table for these reasons have been mentioned in connection with losses of these constituents in the whey.

The significant facts in this table are presented in the figures showing the percentage of fat and protein recovered in the cheese. The recovery of milk fat in single vat lots varied from 86.49% to 94.32%, and averaged 91.13% for all lots during the two seasons. The proportion of proteins recovered during this same period ranged from 73.70% to 80.00% in single vats, and averaged 75.72% for all lots. Such large amounts of fat and protein in the cheese clearly exercise a major influence on the amounts of dry matter in cheese obtainable from any given milk supply.

Studies similar to these have been made in other factories and areas. The general trends of results are identical, but minor differences have been found. Van Slyke (1894a), for example, observed fat recovery in factory-made Cheddar cheese approximating 93% for a season. Milk proteins recovered at the same time averaged more than 76%. The season, factory, quality of milk, and manufacturing skill, all cause variations in these percentage recovery values for milk solids.

**The relation of fat and casein to cheese yield.** The relation between the fat and casein contents of milk and its cheese-producing capacity is shown in figure 5:2. Data from two sources

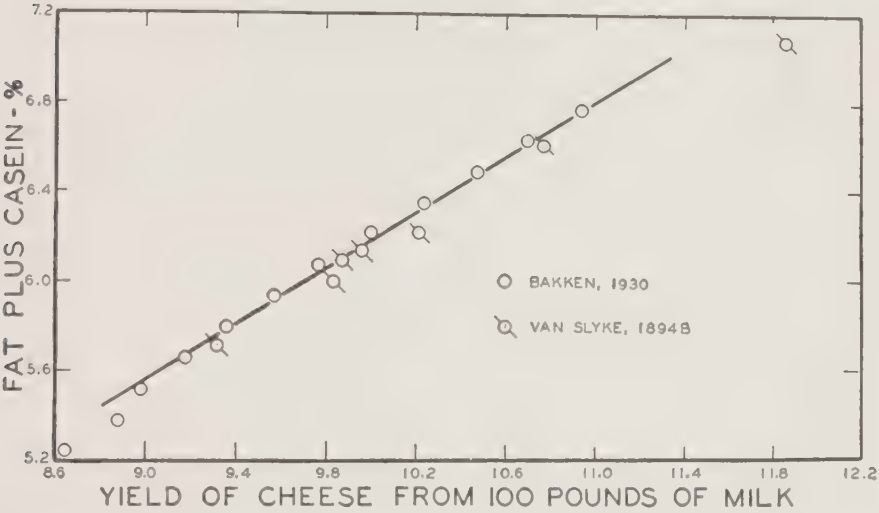


Figure 5:2. The yield of cheese increases according to the sum of percentages of fat and casein in milk. Bakken's data were obtained from 3,874 monthly reports of Wisconsin factories; casein was calculated from the fat reported. Van Slyke's data were obtained from monthly averages from 50 factories in New York; analyses were made from April through October.

are shown: 3,874 monthly reports of factory operations assembled by Bakken (1930) provided the average milk fat percentages and yields of cheese in Wisconsin Cheddar cheese factories; data from 50 factories studied by Van Slyke (1894b) furnished fat and casein analyses on milk and yields of cheese in New York. The large number of observations averaged and plotted in figure 5:2 show an almost straight-line relationship between the fat-plus-casein content of the milk and its percentage yield of cheese. These data indicate why fat and casein are commonly called the "cheese-solids" of milk.

The amount of cheese made per pound of fat in the milk decreases as the fat content of the milk increases. Table 5:5 has been derived from figure 5:2 by reading on the free-hand line of trends the normal yields associated in these factories with the fat-plus-casein content of the milk. Despite the increase in yield per hundred pounds of milk, there is evident in table 5:5 a gradual decline in yield per pound of fat as the fat content of the milk increases. The increase in the percentage yield is explained by the total increase in percentage of cheese solids in the milk. The decreased yield per pound of fat is caused by the decreased proportion of the water-holding protein, casein, in the cheese solids.

TABLE 5:5. RELATION OF FAT AND CASEIN IN MILK TO NORMAL YIELDS OF CHEDDAR CHEESE

(Data from figure 5:2)

| *Fat* | *Casein* | *Fat-plus-casein* | *Percentage yield* | *Yield per pound of milk fat* | *Casein per pound of milk fat* |
|---|---|---|---|---|---|
| % | % | % | % | lb. | lb. |
| 3.2 | 2.18 | 5.38 | 8.70 | 2.72 | 0.68 |
| 3.4 | 2.26 | 5.66 | 9.16 | 2.69 | 0.66 |
| 3.6 | 2.34 | 5.94 | 9.61 | 2.67 | 0.65 |
| 3.8 | 2.42 | 6.22 | 10.06 | 2.65 | 0.64 |
| 4.0 | 2.50 | 6.50 | 10.52 | 2.63 | 0.63 |
| 4.2 | 2.58 | 6.78 | 10.97 | 2.61 | 0.61 |

**Relation of water to yield of cheese.** The water content of cheese varies with many factors. It does not depend upon the water content of the milk. It has been shown in chapter 5 that there is probably a close correlation between the casein-water ratio in cheese and the quality of the cheese: as the casein per pound of water in the cheese decreases so does the quality of the cheese. The amount of water in cheese can be varied by manipulations of several of the routine making operations. It is controlled by the maker within the limits imposed by standards of quality and composition that he must observe. The results of this control under a given set of conditions tend to establish a definite proportion of water to casein in the cheese. By using the percentages of casein in the milk given in table 5:1 and pounds of water in the cheese from 100 pounds of milk listed in table 5:1, it is possible to calculate the pounds of water in the cheese for each pound of casein in the milk. These calculations have been made and assembled in table 5:6. The results indicate that these manufacturers, as a rule, produced cheese with a fairly uniform ratio of 1.5 pounds of water per pound of casein in the milk.

This relationship indicated in table 5:6 suggests that milk containing larger proportions of casein in its cheese producing solids will tend to retain larger amounts of water in the cheese. This is actually true and has been demonstrated experimentally by Price and Germain (1931) and Arbuckle (1913). Standardized milk, for example, used in making Cheddar cheese contains a larger proportion of casein per pound of fat. Cheese made from standardized milk consistently retains more moisture than that made from identical milk which has not been standardized. Only elaborate efforts to reduce the moisture content of the standardized-milk cheese will prevent this condition.

TABLE 5:6. THE RELATION OF THE CASEIN CONTENT OF MILK TO THE WATER RETAINED IN THE CHEESE

(Data from Van Slyke, 1894b)

| *Month* | *Casein in 100 pounds of milk* | *Water in cheese from 100 pounds of milk* | $\frac{\textit{Water in cheese}}{\textit{Casein in milk}}$ |
|---|---|---|---|
| | lb. | lb. | lb. |
| April | 2.29 | 3.56 | 1.55 |
| May | 2.34 | 3.58 | 1.53 |
| June | 2.47 | 3.59 | 1.45 |
| July | 2.43 | 3.58 | 1.47 |
| Aug. | 2.39 | 3.72 | 1.55 |
| Sep. | 2.55 | 3.77 | 1.48 |
| Oct. | 2.81 | 4.51 | 1.60 |
| Average for two seasons | 2.46 | 3.72 | 1.51 |

Manufacturers of cheese tend to maintain an optimum ratio of water to casein. This ratio is associated with maximum quality and efficiency of manufacturing operations. The yield of cheese is directly affected by this ratio.

The extent to which moisture content of cheese can affect yield is illustrated in table 5:7. The data in this table were obtained in the course of the factory studies which have been under consideration. Averages of actual yields per hundred pounds of milk and actual percentages of moisture are shown. From these values have been calculated the pounds of dry matter in the cheese and finally the pounds of cheese which would have been produced if it had contained 35%, 37% and 39% of water.

Variations in moisture content are highly significant in de termining the yield of cheese obtainable from milk of any given composition. Efficiency of factory operations are measured in part by the yield of cheese. Such statistics should always show percentages of moisture in the cheese in order to reveal whether differences in yield should be attributed to percentage of milk solids retained or to amount of water incorporated in the cheese.

TABLE 5:7. THE INFLUENCE OF MOISTURE CONTENT ON THE YIELD OF CHEDDAR CHEESE FROM 100 POUNDS OF MILK
(Data from Van Slyke, 1894b)

| *Month* | *Fat in milk* | *Moisture in cheese* | *Yield of cheese* | *Calculated yields with:* | | |
|---|---|---|---|---|---|---|
| | | | | *35%* | *37%* | *39%* |
| | % | % | lb. | lb. | lb. | lb. |
| April | 3.43 | 38.00 | 9.32 | 8.89 | 9.17 | 9.47 |
| May | 3.58 | 37.11 | 9.65 | 9.34 | 9.63 | 9.95 |
| June | 3.64 | 36.22 | 9.92 | 9.73 | 10.04 | 10.37 |
| July | 3.62 | 36.25 | 9.87 | 9.68 | 9.99 | 10.31 |
| Aug. | 3.84 | 36.69 | 10.15 | 9.89 | 10.20 | 10.53 |
| Sep. | 3.98 | 36.83 | 10.27 | 9.98 | 10.30 | 10.63 |
| Oct. | 4.23 | 38.29 | 11.85 | 11.25 | 11.61 | 11.99 |
| Average for two seasons | 3.75 | 36.84 | 10.08 | 9.79 | 10.10 | 10.44 |

**Estimating yield of cheese.** Fat and casein in milk constitute most of the dry matter in cheese. Trends of results in factory and laboratory studies, some of which have been used in the discussion of this chapter, suggest the possibility of estimating yields of cheese when the composition of the milk and the moisture content of the cheese are known.

In order to make such estimates it is necessary to assume that the milk is of average quality and composition and that it is made into cheese by normal processes. Milk of high quality would be expected to yield more cheese than milk of inferior quality. If milk were of abnormal composition, the amounts of fat and solids-not-fat retained in the cheese would also be abnormal. A skillful maker would probably tend to retain more milk solids in the cheese than an unskillful maker. Variations of such factors would affect the accuracy of estimates which must be based on average values.

It has been shown in this chapter that approximately 91% of the milk fat was retained in the cheese in the factories under observation. This percentage varied somewhat depending upon factory, season, and composition of the milk. An average recovery in the cheese of 93% of the milk fat can be expected under normal conditions. In general it was observed that about one-tenth of a pound of casein was present in the whey from 100 pounds of normal milk. The other constituents of milk and the salt added to the cheese contributed about 9% of the weight of fat and casein retained in the cheese.

The following formula for estimating the percentage yield of cheese from milk has been developed from the general facts summarized in the previous paragraph:

$$\text{Yield} = \frac{(0.93\text{F} + \text{C} - 0.1)\ 1.09}{1.00 - \text{W}}$$

Yield = Pounds of cheese per hundred pounds of milk
F = Pounds of fat per hundred pounds of milk.
C = Pounds of casein per hundred pounds of milk.
W = Pounds of water per pound of cheese.

The application of this formula can be illustrated by an example: Calculate the theoretical yield of cheese with 37% moisture that can be expected from 100 pounds of milk containing 4% fat and 2.5% casein.

Substituting in the formula:

$$\text{Yield} = \frac{[(0.93 \times 4) + 2.5 - 0.1]\ 1.09}{1.00 - 0.37}$$

$$= \frac{(3.72 + 2.5 - 0.1)\ 1.09}{0.63}$$

$$= \frac{6.12 \times 1.09}{0.63}$$

$$= 10.6 \text{ pounds}$$

This method of calculation has been used with considerable accuracy to estimate the actual yield of cheese under varying conditions. It can be modified to calculate yields of other varieties of cheese when proper allowances have been made for differences in losses of milk solids during the process of manufacture.

This method has been modified to give another formula which requires fewer calculations:

$$\text{Yield} = (\text{F} + \text{C})\ \text{N}$$

Yield = Pounds of cheese per hundred pounds of milk.
F = Pounds of fat per hundred pounds of milk.
C = Pounds of casein per hundred pounds of milk.
N = A factor which varies with cheese moisture, see table 5:8.

The value of N increases as the moisture content of the cheese increases. Values for N for amounts of moisture ranging from 30% to 49% are given in table 5:8. An example will illustrate the application of this short method of estimating yield: What is the yield of cheese to be expected from 100 pounds of milk containing 3.4% fat and 2.26% casein when the cheese contains 37% moisture?

TABLE 5:8. VALUES FOR "N," THE MOISTURE FACTOR, TO BE USED IN THE FORMULA * : YIELD = (F + C) N

| *Moisture* % | *"N"* | *Moisture* % | *"N"* |
|---|---|---|---|
| 30 | 1.47 | 40 | 1.71 |
| 31 | 1.49 | 41 | 1.74 |
| 32 | 1.51 | 42 | 1.77 |
| 33 | 1.53 | 43 | 1.80 |
| 34 | 1.555 | 44 | 1.835 |
| 35 | 1.58 | 45 | 1.87 |
| 36 | 1.605 | 46 | 1.90 |
| 37 | 1.63 | 47 | 1.94 |
| 38 | 1.655 | 48 | 1.98 |
| 39 | 1.68 | 49 | 2.015 |

* Yield = pounds of cheese per 100 pounds of milk
F = pounds of fat in 100 pounds of milk
C = pounds of casein in 100 pounds of milk
N = the moisture factor which varies with the moisture content of the cheese.

Substituting in the formula:

$$\begin{aligned} \text{Yield} &= (3.4 + 2.26)\ 1.63 \\ &\phantom{=}\ 5.66 \times 1.63 \\ &\phantom{=}\ 9.23 \text{ pounds} \end{aligned}$$

In this same manner the theoretical yields of Cheddar cheese expected from normal milk have been calculated and are tabulated in table 5:9. The table includes milk with fat contents ranging from 3.0% to 4.5% and cheese with moisture contents ranging from 34% to 41%.

TABLE 5:9. THEORETICAL YIELDS OF CHEDDAR CHEESE CALCULATED BY THE FORMULA * : YIELD = (F + C) N

| *Milk fat* | *Moisture content of cheese* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *34%* | *35%* | *36%* | *37%* | *38%* | *39%* | *40%* | *41%* |
| % | lb. | lb. | lb. | lb. | lb. | lb. | lb. | lb. |
| 3.0 | 7.905 | 8.058 | 8.186 | 8.313 | 8.441 | 8.568 | 8.721 | 8.874 |
| 3.1 | 8.148 | 8.279 | 8.410 | 8.541 | 8.672 | 8.803 | 8.960 | 9.118 |
| 3.2 | 8.366 | 8.500 | 8.635 | 8.769 | 8.907 | 9.038 | 9.200 | 9.361 |
| 3.3 | 8.583 | 8.722 | 8.860 | 8.998 | 9.136 | 9.274 | 9.439 | 9.605 |
| 3.4 | 8.801 | 8.943 | 9.084 | 9.226 | 9.367 | 9.509 | 9.679 | 9.848 |
| 3.5 | 9.019 | 9.164 | 9.309 | 9.454 | 9.599 | 9.744 | 9.918 | 10.092 |
| 3.6 | 9.237 | 9.385 | 9.534 | 9.682 | 9.831 | 9.979 | 10.157 | 10.336 |
| 3.7 | 9.454 | 9.606 | 9.758 | 9.910 | 9.404 | 10.214 | 10.397 | 10.579 |
| 3.8 | 9.672 | 9.828 | 9.983 | 10.139 | 10.294 | 10.450 | 10.636 | 10.823 |
| 3.9 | 9.880 | 10.049 | 10.208 | 10.367 | 10.526 | 10.665 | 10.876 | 11.066 |
| 4.0 | 10.108 | 10.270 | 10.433 | 10.595 | 10.758 | 10.920 | 11.115 | 11.310 |
| 4.1 | 10.325 | 10.491 | 10.657 | 10.823 | 10.989 | 11.155 | 11.354 | 11.554 |
| 4.2 | 10.543 | 10.712 | 10.882 | 11.051 | 11.221 | 11.390 | 11.594 | 11.797 |
| 4.3 | 10.761 | 10.934 | 11.107 | 11.280 | 11.453 | 11.626 | 11.833 | 12.041 |
| 4.4 | 10.978 | 11.155 | 11.331 | 11.508 | 11.684 | 11.861 | 12.073 | 12.284 |
| 4.5 | 11.196 | 11.376 | 11.556 | 11.736 | 11.916 | 12.096 | 12.312 | 12.528 |

* Yield = pounds of cheese per 100 pounds of milk
F = pounds of fat in 100 pounds of milk
C = pounds of casein in 100 pounds of milk
N = moisture factor, see table 5:8.

## REFERENCES

Arbuckle, W. S. (1943). Southern Dairy Products J., *33*, No. 6 : 12.

Bakken, H. H. (1930). Wis. Agr. Expt. Sta., Res. Bul. 100.

Price, W. V. and Germain, Leo (1931). Wis. Agr. Expt. Sta., Res. Bul. 108.

Van Slyke, L. L. (1894a). N. Y. (Geneva) Agr. Expt. Sta., Bul. 82. New series.

Van Slyke, L. L. (1894b). N. Y. (Geneva) Agr. Expt. Sta., Bul. 65. New series.

## CHAPTER 6

# METHODS OF PAYING FOR MILK FOR CHEESE MAKING

Methods of paying for milk at cheese factories have been debated for many years. Before 1890 milk was usually paid for according to its weight alone. At that time there was little known about the relation between milk constituents and yield of cheese. Until 1890, when the Babcock test became available, there was no practical, factory method of evaluating milk composition. The investigations of milk composition and its relation to cheese yield in the years immediately following 1890 disclosed that the fat content of milk was a useful index for paying for milk. It was further shown that it was not a perfect index because as the fat content of milk increased the yield of cheese per pound of fat decreased. Even today, milk producers sometimes find it difficult to understand this relationship and to reconcile it with the fact that increasing amounts of fat in the milk increase the yield of cheese per pound of milk.

About 1892 the fat test was being used in factory practice for determining the money value of milk delivered by farmers. Naturally there were many objections before it was almost universally adopted. Owners of cows producing milk of less than average fat content suffered because they received less than when their payments were based only on the weight of milk. They attacked the reliability and accuracy of paying by fat test. They questioned the method of testing, the analytical skill of the makers, the accuracy of the glassware, and the honesty of those who made the tests. The makers themselves objected to the system when they became the target for criticisms. Each new generation of dairymen seems at times to experience the same doubts despite the wealth of information on the reliability of the method and the elaborate precautions taken to insure honesty and fair dealing in its application. Many factories today are glad to permit the farmers to hire their own analysts to test the milk for fat and to check the weights of milk at the intake.

## METHODS OF PAYING FOR MILK

Some of the more common methods of paying for milk are: (1) by weight or volume; (2) by fat content; (3) by adding to the percentage of fat a constant value like 2, 1, or 0.6; (4) by amount of fat and casein, with the latter calculated or determined analytically; and (5) by price differential.

In order to illustrate the basic calculations of the different methods of payment, we shall use the statement of one factory and calculate the amount of money due to one of its milk suppliers, Patron A. During the period for which payment is to be calculated, this factory received from all patrons a total of 100,000 pounds of milk containing 3,500 pounds of fat which is equivalent to 3.5% fat. The total income from all sales derived from this milk less costs of operation left a net income of $2,000 for distribution to the patrons. Patron A delivered 5,000 pounds of the total amount of milk received; his milk contained 200 pounds of fat or 4% of fat.

**Payment by weight.** Under this plan, each patron receives a share of the net income in proportion to the weight of milk delivered. This share is calculated by dividing the net income for the period of payment by the total weight of milk delivered by all the patrons during that period. This gives the value of a pound of milk. This value multiplied by the pounds of milk delivered by the individual patron gives the amount of money due that patron. The calculations for the example chosen are:

a) $\frac{\$2000 \text{ net income}}{100{,}000 \text{ lb. milk}} = \$0.020$, the value of 1 lb. milk;

b) 5000 lb. milk $\times$ \$0.020 $=$ \$100, the amount due Patron A.

Payments for milk by weight alone are simple to calculate, but the method discourages the delivery of milk with more than average fat content; it encourages selection of cattle for large volume milk production rather than for high yield of milk solids; and it tends to encourage adulteration of milk by watering or skimming. Despite its unfairness, this method of payment was commonly used in one of the most concentrated cheese-producing areas as recently as 1930.

**Payment by fat content.** This plan gives each patron the same amount of money for each pound of fat in the milk delivered. This is the system most commonly used in cheese factories. The value of one pound of fat is determined by dividing the net income for the period of payment by the total number of pounds of fat delivered by all patrons. The pounds of fat delivered by the individual patron multiplied by the value of one pound of fat gives the amount of the net income to which the patron is entitled.

The amount due Patron A when payment is by fat content, is calculated as follows:

a) $\frac{\$2{,}000 \text{ net income}}{3{,}500 \text{ lb. fat}} = \$0.5714$, the value of 1 lb. of fat;

b) 5,000 lb. milk × 4% = 200 lb., the fat delivered by Patron A;

c) 200 lb. fat × $0.5714 = $114.28, the amount due Patron A.

Payment for milk on the basis of its fat content gives each patron his fair share of the net income providing the difference between the highest and lowest testing milks does not exceed 1%. This method recognizes the relation between milk composition and cheese yield except in extreme variations of test; it is practical to apply; it discourages the watering of milk; and it encourages dairy herd improvement. It does not prevent removal of skim milk at the farm, but such tampering can be detected by using the lactometer in conjunction with the fat test to discover maladjustment in the proportions of fat and solids-not-fat in the milk.

**Payment by "fat plus 0.6."** This plan is designed to compensate for the fact that increasing amounts of fat in the milk are associated with decreasing yield of cheese per pound of fat. This compensating adjustment is made by adding 0.6 to the per cent of fat in the milk delivered by each patron. In the example we have been using Patron A delivered milk with 4.0% fat. To this test is added 0.6. The sum, 4.6%, is then used to calculate the number of units of "fat plus 0.6" in his milk. (Constant values of 1 and 2 have also been used instead of 0.6 to add to the per cent of fat in the milk to calculate payments. They do not distribute the returns for the cheese as equitably as the use of the constant, 0.6.)

The value of one unit of "fat plus 0.6" is calculated by dividing the net income of the factory by the total units of "fat plus 0.6" in the factory's milk supply. Each patron's share is obtained by multiplying the value of one unit by the number of units of "fat plus 0.6" in the milk delivered by the patron.

The amount due Patron A by the "fat plus 0.6" method in the example we are using is calculated below:

a) $100{,}000 \times (3.5\% + 0.6) = 4{,}100$ units of "fat plus 0.6" in the factory milk supply;

b) $\frac{\$2000 \text{ net income}}{4{,}100 \text{ units}} = \$0.4878$, value of one unit of "fat plus 0.6";

c) 5000 lb. milk $\times (4.0 + 0.6) = 230$, units of "fat plus 0.6" in milk of Patron A;

d) 230 units $\times$ \$0.4878 = \$112.19, amount due Patron A.

This method of payment returns to each patron the value of his milk in terms of its cheese-yielding capacity. It tends to encourage both skimming and watering of milk.

**Payment by fat plus casein.** This plan was devised to distribute the net income according to the amount of cheese produced by the milk regardless of its composition. Values for casein may be determined by analysis or they may be calculated from the fat content of the milk by the formula:

$$\text{Per cent casein} = 0.4 \text{ Fat} + 0.9$$

Values of fat-plus-casein for a wide range of fat percentages are shown in table 6:1 in order to simplify the calculations for payment.

The value of one unit of "fat-plus-casein" is determined by dividing the net income of the factory by the total units of "fat-plus-casein" in the factory's milk supply. Each patron's share is then calculated by multiplying the value of one unit by the number of units of "fat-plus-casein" in the milk delivered by that patron.

The amount due Patron A in the example already cited is determined as follows:

a) The units of "fat-plus-casein" in the milk supply testing 3.5% are found in table 6:1; they are 5.80 units per hundredweight of milk;

b) 1000 hundredweight of milk $\times$ 5.80 = 5,800, the units of "fat-plus-casein" in the factory milk supply;

c) $\frac{\$2000 \text{ net income}}{5{,}800 \text{ units}} = \$0.3448$, the value of one unit of "fat-plus-casein" in the factory milk supply;

d) The units of "fat-plus-casein" in the 4% milk supplied by Patron A are found in table 6:1 to be 6.50 per hundredweight of milk;

e) 50 hundredweight of milk × 6.50 = 325, the units of "fat-plus-casein" in the milk belonging to Patron A;

f) 325 units × $0.3448 = $112.06, the amount due Patron A.

TABLE 6:1. UNITS OF "FAT + CASEIN" IN 100 POUNDS OF MILK OF NORMAL COMPOSITION

| *Fat in milk* | *Units of Fat + Casein* | *Fat in milk* | *Units of Fat + Casein* | *Fat in milk* | *Units of Fat + Casein* |
|---|---|---|---|---|---|
| % | | % | | % | |
| 3.00 | 5.10 | 3.85 | 6.29 | 4.70 | 7.48 |
| 3.05 | 5.17 | 3.90 | 6.36 | 4.75 | 7.55 |
| 3.10 | 5.24 | 3.95 | 6.43 | 4.80 | 7.62 |
| 3.15 | 5.31 | 4.00 | 6.50 | 4.85 | 7.69 |
| 3.20 | 5.38 | 4.05 | 6.57 | 4.90 | 7.76 |
| 3.25 | 5.45 | 4.10 | 6.64 | 4.95 | 7.83 |
| 3.30 | 5.52 | 4.15 | 6.71 | 5.00 | 7.90 |
| 3.35 | 5.59 | 4.20 | 6.78 | 5.05 | 7.97 |
| 3.40 | 5.66 | 4.25 | 6.85 | 5.10 | 8.04 |
| 3.45 | 5.73 | 4.30 | 6.92 | 5.15 | 8.11 |
| 3.50 | 5.80 | 4.35 | 6.99 | 5.20 | 8.18 |
| 3.55 | 5.87 | 4.40 | 7.06 | 5.25 | 8.25 |
| 3.60 | 5.94 | 4.45 | 7.13 | 5.30 | 8.32 |
| 3.65 | 6.01 | 4.50 | 7.20 | 5.35 | 8.39 |
| 3.70 | 6.08 | 4.55 | 7.27 | 5.40 | 8.46 |
| 3.75 | 6.15 | 4.60 | 7.34 | 5.45 | 8.53 |
| 3.80 | 6.22 | 4.65 | 7.41 | 5.50 | 8.60 |

This method of payment returns to each patron the amount of money earned by the cheese-producing capacity of the milk. When the casein is determined by analysis the extra test is laborious and not practical in the hands of an unskilled analyst. When the casein is estimated from the fat content of the milk the method of payment is more easily applied. Under such circumstances there can be some injustice because there may be more or less casein in the milk than the calculations show. This method of payment has not attained any general acceptance in commercial practice.

McDowall (1936) has presented an excellent discussion of the problem of paying for milk at cheese factories. He advocates the testing of the milk for both fat and casein. Costs of handling milk and manufacturing cheese are taken into consideration separately in what McDowall calls the "Costed Cheese" system. The method does not contribute any greater accuracy in distributing returns than the Froker-Hardin method. The McDowall method has been used successfully in New Zealand.

**Froker-Hardin method.** Froker and Hardin (1942) proposed a general plan of payment for milk which would be applicable to all types of dairy products. Their plan of payment for cheese factory practice has two parts: first, they determine the price per hundredweight of milk of a given test; second, they calculate the price differential for each 0.1% fat. They observed that for each increase of 0.1% of fat in the milk there was an increase of 0.23 lb. of cheese containing 37% moisture. (See table 5:9) They further observed that in addition to the extra cheese from higher testing milk, some additional fat could be recovered in separating the whey. This extra fat they found amounted to about 0.004 lb. fat for each 0.1% change in the fat content in the milk.

In the Froker-Hardin plan the cheese factory price for 100 pounds of milk of average test is determined by dividing the net income by the hundredweight of milk purchased from the producers. The average prices received by the factory for cheese and whey cream are used to calculate how much to change the price per hundredweight for milk with more or less than the average amount of fat. Only the average expense of handling and marketing cheese and whey cream are deducted from these prices because the factory does not handle extra milk or less milk as the fat content increases or decreases. These expenses are called "direct costs" and include only those costs which arise after the milk is made into cheese curd and the whey cream has been separated from the whey. These costs include labor, supplies, sales expense and a reasonable share of the overhead expenses involved in handling, storing, and marketing cheese and whey cream.

Froker and Hardin (Anonymous, 1942) approved this explanation of their method of payment:

"Let us assume that the factory received 300,000 pounds of milk having an average test of 3.83% fat, that it had $6485 to distribute after total operating costs, including depreciation and reserves, had been deducted, that it received an average price of 22¢ per pound of cheese and 36¢ per pound of fat in whey cream, and that it had direct costs of 1.5¢ per pound of cheese and 1¢ per pound of fat in whey cream.

"The money available for distribution is divided by the hundredweight of milk to get the price for the average test of milk:

$6485 ÷ 3,000 hundredweight = $2.162 — the price of 3.83% milk.

"How much should that price be changed for each 0.1% fat when the milk is manufactured into cheddar cheese of 37% moisture? The yield of cheese will normally vary 0.23 pound for each 0.1% change in the test of milk. Subtract the direct costs from the price of cheese and multiply the result by .23 to determine the value of the extra cheese. For each point change in the fat content of the original milk there is normally .004 pound of fat change in the whey cream. Multiply this last figure by the price of fat in whey cream after direct costs are deducted. The whey itself will undergo no measurable change in value. These two parts of the formula can be put together for the determination of the price differential as follows:

.23 (Cheese price — Direct costs)
PLUS
.004 (Cream price — Direct costs)
EQUALS
Price differential

Substituting the actual figures gives this result:

$$.23\,(22¢ - 1.5¢) + .004\,(36¢ - 1¢) = 4.9¢$$

"The $2.162 is the price for 3.83% milk and the price differential is 4.9¢ for each 0.1% fat. It is now necessary to determine the price of 3.5% milk, since that is the test for which milk prices must be quoted on a hundredweight basis in Wisconsin. This is not difficult. The plant test of 3.83% fat is 3.3 points above the 3.5% standard. All that is necessary is to multiply the price differential by 3.3 and subtract the result from the price of 3.83% milk:

$$\$2.162 - (3.3 \times 4.9¢) = \$2.00$$

"The factory can now announce that the price it will pay producers will be $2.00 per hundredweight of 3.5% with 4.9¢ differential per point of test variation."

The factor of 0.23 in the Froker-Hardin formula is used only when the cheese contains 37% moisture. When the percentage of moisture in the cheese is 35% the factor should be 0.22; for

39% moisture, 0.235; for 42% moisture, 0.25; and for 47% moisture, 0.275. Intermediate values can be easily determined from table 5:9.

When standardized milk is used for cheese making, the following formula is suggested by Froker and Hardin (1942)

.1466 (Cheese price — Direct costs)
PLUS
.0497 (Cream price — Direct costs)
EQUALS
Price differential.

The first part of the formula represents the value of the cheese associated with 0.1% fat variation. The second part of the formula represents the value of the cream removed by standardizing and the value of cream recovered from the whey. Both of these values are given for differences occasioned by the variation of 0.1% fat in the milk.

Froker and Hardin (1942) state; "The factors .1466 and .0497 are for cheese with 38% moisture and 51% fat in the dry matter and with the extra fat removed in the form of 35% cream. . . . When the extra fat is removed in the form of 20% cream the factors should be .1355 and .0536, respectively. For 30% cream these factors should be changed to .1443 and .0505, and for 40% cream to .1481 and .0492, respectively. The test of the original milk before standardizing would also have an influence, but the adjustment is believed to be too small and too complicated to be taken into account here."

The Froker-Hardin plan for paying for milk has the merit of fitting into a general plan of payment for milk at all types of dairy plants and markets. Other formulas of course are used for other products but the principles of deriving them are practically identical to those which have been shown for cheese. This plan makes a suitable allowance for the whey cream as well as cheese yield. It has the disadvantage of being based on average yields of varying amounts of moisture.

**Comparison of methods of payment.** Table 6:2 compares, in a simple manner, the results of using the different methods of payment that have been discussed. Data are given for 5 lots of milk, each of which weighs 100 pounds. Fat and casein contents of the milk, yields of cheese with 37% moisture and whey-fat yields equalling 7% of the fat in the milk are shown. Values of the cheese and whey fat produced by each lot of milk are totaled to show the "earned income" from each lot of milk.

TABLE 6:2. COMPARISON OF METHODS OF PAYMENT

| *Lot number* | *1* | *2* | *3* | *4* | *5* | *Totals* |
|---|---|---|---|---|---|---|
| Amount of milk, lb. | 100 | 100 | 100 | 100 | 100 | 500 |
| Fat in milk, lb. | 3 | 3.5 | 4.0 | 4.5 | 5.0 | 20 |
| Casein in milk, lb. | 2.1 | 2.3 | 2.5 | 2.7 | 2.9 | 12.5 |
| Cheese, 37% moisture, lb. | 8.30 | 9.45 | 10.60 | 11.75 | 12.90 | 53.0 |
| Fat in whey cream, lb. | .21 | .245 | .28 | .315 | .35 | 1.4 |
| Cheese value * at 20¢ | 1.66 | $1.89 | $2.12 | $2.35 | $2.58 | $10.60 |
| Whey fat value * at 50¢ | .105 | .122 | .140 | .157 | .175 | .70 |
| "Earned Income" | $1.765 | $2.012 | $2.260 | $2.507 | $2.755 | $11.30 |
| Method of payment: | *Amounts returned for 100 lb. milk* | | | | | |
| Weight | $2.260 | $2.260 | $2.260 | $2.260 | $2.260 | $11.30 |
| Fat content | 1.695 | 1.977 | 2.260 | 2.542 | 2.825 | 11.30 |
| Fat + 0.6 | 1.769 | 2.014 | 2.260 | 2.506 | 2.751 | 11.30 |
| Fat + casein | 1.773 | 2.017 | 2.260 | 2.503 | 2.747 | 11.30 |
| Froker-Hardin | 1.78 | 2.02 | 2.26 | 2.50 | 2.74 | 11.30 |

* Net values after costs have been deducted.

The money value of the cheese and whey fat from all 5 lots of milk equals $11.30, as shown in table 6:2. When payments for these 5 lots of milk are calculated on the weight basis, the returns are $2.26 per hundredweight for each lot. Milk in the low-fat lots is paid more than it "earned," while those lots in the high-fat groups are under-paid. Because of the wide range of fat contents used in this example, the payments by the fat content are less than the "earned income" of the low-fat lots and in excess of "earned income" of high-fat lots. The other three methods of payment approximate the "earned incomes" of the various lots of milk with reasonable accuracy. Such methods of payment are fair to all classes of milk regardless of composition. When the range of fat content between the lowest and highest testing milk is 1% or less then the accuracy of the fat content method approximates that attained by the fat + casein, the fat + 0.6, and the Froker-Hardin methods.

**Cheese factory statements.** When farmers receive their checks for the milk they have delivered, they are commonly given a statement by the management of the factory. This factory statement usually shows how the funds of the factory have been handled, how the receipts have been distributed to the patrons, and how efficiently the factory has operated. Patrons of cooperatively owned and operated factories expect

## TABLE 6:3. A MODEL CHEESE FACTORY STATEMENT
(Bakken, 1929)

Factory *Square Deal* P. O. *Ames, Wis.*

STATEMENT for Month of *September*, 1929.

### STATEMENT OF RECEIPTS AND DISBURSEMENTS

| | | Receipts | Disbursements |
|---|---|---|---|
| A. | Received from cheese sales | $3,711.08 | |
| B. | Received from whey cream sales | 217.92 | |
| C. | Other receipts | | |
| D. | Add (A + B + C) | 3,929.00 | |
| E. | Underpayment, last statement (add) | 1.26 | |
| | Overpayment, last statement (subtract) | | |
| F. | Total receipts | $3,930.26 | |
| G. | Paid for making cheese 2½¢ | | $ 376.40 |
| H. | Other cash expenses. Whey cream ½ (portion) | | 108.96 |
| | Salaries, fees, etc. | | 8.00 |
| I. | Total cash expenses (G + H) | | 493.36 |
| J. | Paid Patrons | | 3,438.28 |
| | Add (I + J) | | 3,931.64 |
| K. | Underpayment (add) | | |
| | Overpayment (Subtract) | | 1.38 |
| L. | Total disbursements (Should balance with F) | | 3,930.26 |

### FACTORY REPORT

| | | | | |
|---|---|---|---|---|
| M. | Pounds milk (Milk sheet) | | | 150,260 |
| N. | Pounds butterfat (Patron's totals) | | | 5,636.48 |
| O. | General average test (N-:-M) | | | 3.751 |
| P. | Pounds cheese: (Styles) | *Horns* | 8,000 | |
| | | *Daisies* | 7,056 | |
| | Total pounds | | 15,056 | |
| Q. | Yield-lbs. cheese per 100 lbs. milk (P-:-M) | | | 10.02 |
| R. | Pounds cheese per lb. fat (P-:-N) or (Q-:-O) | | | 2.671 |
| S. | Price per pound cheese (A-:-P) average | | | $ .2464 |
| T. | Price per pound fat (J-:-N) net | | | .6100 |
| U. | Price per 100 pounds (3.5%) milk (3.5 × T.) net | | | 2.135 |
| V. | Value whey cream per 100 lbs. milk (B-:-M) | | | .145 |
| W. | Expense per pound cheese (I-:-P) | | | .0327 |

### PATRON'S ACCOUNT

Name *John Doe*

| | | | | |
|---|---|---|---|---|
| X. | Pounds milk | 9,000 | | |
| Y. | Per cent fat in the milk | 3.80 | | |
| Z. | Pounds fat (X × Y) | 342.00 | | |
| aa. | Due patron (Z × T) | | | $208.62 |
| bb. | Cheese withdrawn, 10 lbs. @ 25¢ | | 2.50 | |
| cc. | Butter withdrawn, 15 lbs. @ 50¢ | | 7.50 | |
| dd | Cash advanced | | 80.00 | |
| ee. | Total debits | | | 90.00 |
| ff. | Check for balance (aa-ee) | | | $118.62 |

such statements at every period of payment. Most factories render similar statements.

Bakken (1929) has discussed the details of the necessary calculations in preparing a factory statement. His model statement is shown in table 6:3.

## REFERENCES

Anonymous (1942). Economic Information for Wisconsin Farmers. *13,* No. 4:1.

Baken, H. H. (1929) Coll. of Agr., Ext. Service, Univ. Wis., Circ. 233.

Froker, Rudolph K. and Hardin, Clifford M., (1942). Wis. Agr. Expt. Sta., Res Bul 143

McDowall, F. H., (1936). New Zealand J. Sci. and Technol., *18,* 137.

## CHAPTER 7

# MICROORGANISMS AND CHEESE MAKING

Milk is a perishable product. It begins to change as soon as it leaves the cows' udder. Some of these changes are physical, such as the rising of fat globules; others are chemical, such as oxidation of fat; still others are changes caused by biological agents, such as the souring of milk by lactic acid producing bacteria. Changes brought about by microorganisms are extremely important in the manufacture of cheese. The nature and extent of their actions in milk depend upon the conditions under which the milk is produced and held. The microorganisms concerned are chiefly bacteria but there may be yeasts and sometimes molds involved.

**Microorganisms and changes in milk.** Milk is an excellent medium to support the growth of microorganisms. The kinds of bacteria that actually do grow in it depend largely on the temperature at which the milk is held. Milk sours at ordinary room temperature. *Streptococcus lactis* is the typical organism primarily responsible for this change because it usually happens to get into milk in the course of milking and storing in common milk utensils. Room temperature favors the growth of this organism. But while most samples of milk sour when subjected to this same treatment, they all do not taste and smell alike. Such differences are indicative of the presence and action of other organisms and perhaps enzymes. If the same samples were held at higher or lower temperatures, the changes would be quite different because the activity of other organisms in the milk would be favored more than that of S. *lactis*. Figure 7:1 illustrates this general relationship.

These examples of changes in milk on holding suggests that milk always contains some microorganisms. This is practically true. Some are in the milk when it is drawn from the cow's udder; some are present in the utensils into which the milk is drawn. Dust from the air, particles of soil, feed, bedding, and the like, might be found in carelessly handled milk. Each would contribute microorganisms characteristic of their source. These sources might be the digestive tract of the cow, or the soil, or water. Some might be injurious, while others might be helpful.

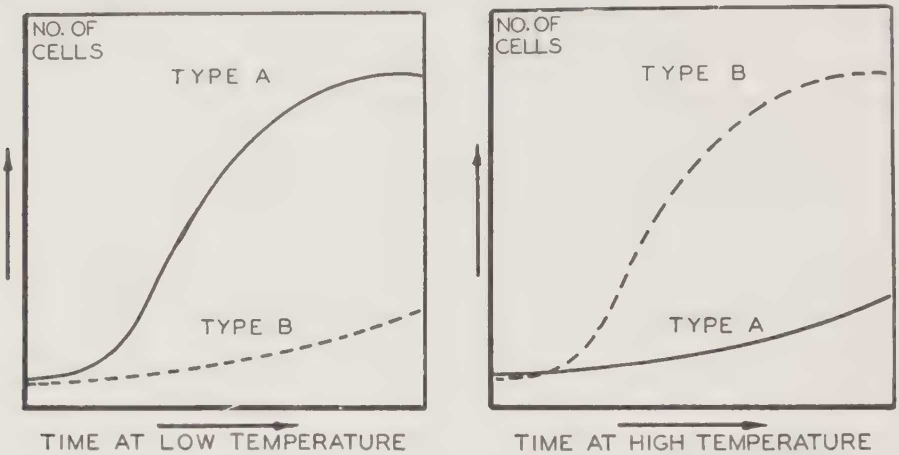


**Figure 7:1. Conditions in making cheese that will encourage the development of one type of organism may limit or inhibit the growth of another type. This diagram shows the possible effect of the temperature factor.**

Cheese makers encourage the desirable organisms by establishing conditions to favor their growth and activity. This was done by successful makers long before the existence of bacteria in milk had been demonstrated. They observed the effects of treatments of milk and curd. When they were pleased, they tried to use these treatments regularly. In this way the traditional methods of cheese making became established. It was only in the last half of the nineteenth century that men learned about bacteria and something of what they could do for mankind. But long before they reached this understanding, they were following practices which helped determine the nature and extent of fermentation processes and, among them, that of cheese making.

Before they were aware of bacteria and their activities, some makers realized that unclean conditions of milk handling in the dairy were associated with undesirable changes in the cheese. Thomas Tusser, about 400 years ago, wrote:

"When cheeses in dairy have Argus, his eyes,
Tell Cisley the fault in her housewifery lies."

Even today we have to remind modern "Cisleys" that their carelessness in cleaning milk pails and taking care of the milk may cause the hundred eyes of Argus in cheese.

Long before cheese makers had cultures of desirable organisms they were saving a little whey from one day to add to the cheese milk on the next day in order to produce more surely the desired physical properties of the curd and cheese.

**Microorganisms and varieties of cheese.** Milk is manufactured into many varieties of cheese. Each type can be distinguished from the others by some differences which can be attributed directly to the activity of certain kinds of organisms. In a few types of cheese, like Cottage, Camembert, blue mold, and Swiss cheese, the relation of specific organisms to certain desired characteristics has been established. These organisms are used and their activities are intelligently controlled in the making of cheese. In other types, of which Cheddar is a notable example, the biological ripening agents are not so well known. In these types the functions of the acid-producing organisms during curd making and in the beginning stages of ripening are well established. Beyond these early stages of making, knowledge of specific ripening agents is still incomplete. These unknown agents may be enzymes, or microorganisms, or both. They may originate in the milk, in the rennet extract that is added to coagulate the milk, or by the growth and distintegration of bacterial cells.

**Controlled environment of microorganisms in cheese making.** Hastings (1943) explained that the art of cheese making

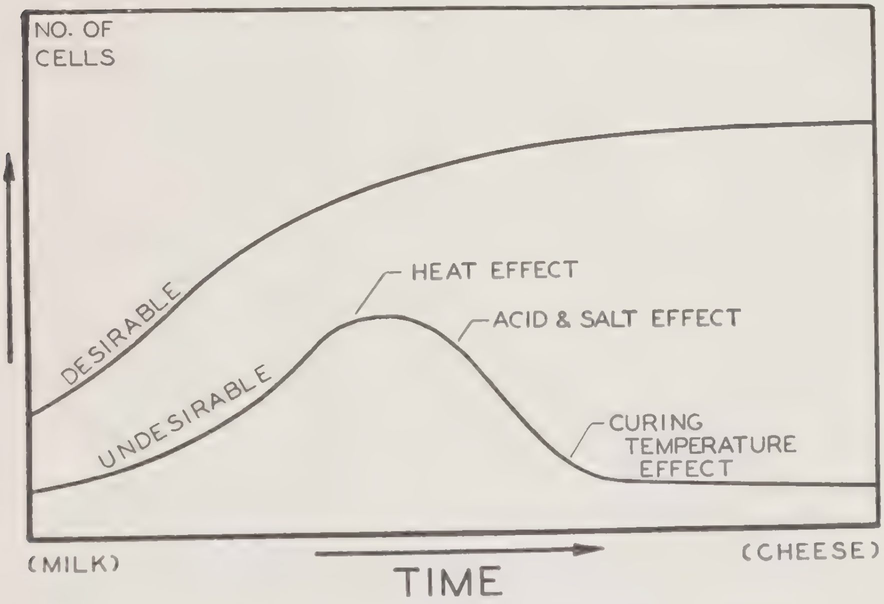


Figure 7·2. Desirable organisms tend to thrive under an environment that discourages the undesirable types. This diagram illustrates how this principle acts in the process of cheese making.

establishes the proper controlled environment for the biological agents of cheese making and ripening. This controlled environment includes such factors as: acidity, moisture, salt, temperature of curing, and, in some varieties, control of conditions affecting the growth of microorganisms on the surfaces of the cheese during curing. Chance and circumstances determine the nature and extent of the bacterial and enzyme contents of the milk; the maker, by the exercise of his art, attempts to direct and control the course and extent of action of these biological agents. Unusual variations in the raw materials always tend to cause corresponding variations in the finished product. Ideal practices therefore, attempt to minimize these unusual variations by every possible means. Control of the microorganisms in milk and starter is vital to such practices.

**Control of microorganisms in milk for cheese.** Control of milk quality has always been used as a method of regulating the course of biological changes in the making of cheese. The increased use of milking machines, milk houses with proper cleaning facilities, and more efficient cooling practices have all influenced making procedures. Makers have found that improved sanitary methods of handling milk, more efficient methods of cooling, and pasteurization have made it necessary for them to attain the proper acidity development at the beginning of the making process by means other than natural souring. The general trend toward lower bacterial counts in the raw milk creates an additional incentive for the development of making practices which will add the proper organisms to the milk in the correct proportions.

Pasteurization of milk is increasingly used as a method of controlling the numbers of organisms in milk for cheese making. Pasteurization practically eliminates the characteristic flora and enzyme contents of normal milk. At least the minimum numbers of desirable organisms needed for cheese making must be restored to milk after pasteurization. The thermoduric organisms that do survive pasteurization are usually present in insignificant numbers but occasionally among such survivors are spore-forming anaerobes which cause gas defects.

Control of microorganisms in either raw or pasteurized milk is further accomplished by addition of cultures of organisms to produce the desirable changes in the making and curing processes. These cultures are called **starters.** The types of organisms used in starters are limited in number. It is practically certain that the starters commonly used today do not contain all of the organisms that are found in the most desirable cheese. This is evident, for example, in cheese made from pasteurized milk. It is probable that inactivation of enzymes, as well as elimination of bacteria by the heat treatment, accounts in part for the slower curing of the usual types of pasteurized-milk cheese. But the addition of common starters does not restore the normal flora of desirable raw milk, if one can judge this fact by the ripening of the cheese made from it. It seems most probable that all of the essential organisms for ripening most varieties of cheese are still unknown. In varieties of cheese like Cheddar the problem is complicated because the characteristic flavors probably represent the work of the enzymes of milk and rennet as well as the effects of many kinds of organisms acting together or in succession. Some of these organisms are undoubtedly significant only because they establish conditions suitable for the growth of those bacteria which later succeed them and produce the desirable characteristics in the cheese.

## Desirable Microorganisms

The microorganisms commonly found in most of the important varieties of cheese have been studied. It is not within the scope of this text to discuss all of them. Only those will be

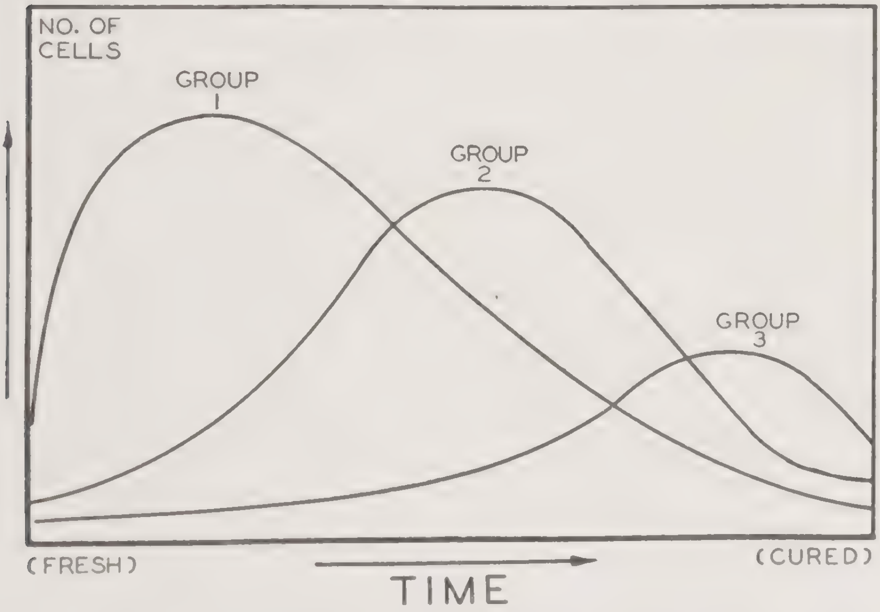


Figure 7:3. As cheese ripens, first one and then another group of organisms tends to dominate the bacterial flora of the cheese.

considered that pertain to common varieties of cheese of commercial significance in this country.

**The sequence of desirable microorganisms in cheese.** Each type of cheese is distinguished by a characteristic sequence of desirable organisms that normally grow in the curd and cheese. The fundamental reasons for this orderly succession were recently stated by Hastings (1943) and have already been mentioned in this discussion in connection with controlled environment. The sequence of desirable microorganisms in cheese can be shown by considering a limited number of specific varieties. The principle of the sequence idea is illustrated in figure 7:3.

**Starters in cheese making.** The first group of organisms dominant in cheese is the one originating in the cultures of modern cheese-making technique.

The manufacture of the common varieties of cheese is facilitated by adding cultures or starters. The starter most commonly used produces lactic acid chiefly and is known as a **lactic starter.** It contains *Streptococcus lactis* in one or more of its several varieties, or *Streptococcus cremoris*, or combinations of them. Associated with these organisms are the aroma-producing bacteria, *Leuconostoc citrovorum* and *Leuconostoc dextranicum*. *L. citrovorum* acts on citric acid compounds of milk to form carbon dioxide, certain volatile acids and acetylmethylcarbinol. *L. dextranicum* ferments lactose to lactic acid. This type of "lactic starter" is used in making all of the kinds of cheese described in this text. It provides the first in the sequence of desirable organisms involved in cheese making.

In the making of some types of cheese, like Swiss, the curd may be exposed to high temperatures. Heat resistant, acid-forming organisms are used in starters for such types of cheese. *Streptococcus thermophilus* and *Lactobacillus helveticus* or closely related organisms or combinations of them are found in such heat-resistant starters.

The organisms in starters are needed chiefly for the acid they produce. This influences the coagulation of the milk and the firming of the curd; it is necessary to form proper body and texture; it affects the flavor of the fresh and ripened cheese by its presence and by establishing conditions that directly determine the nature and extent of the activities of all other organisms in the curd and cheese.

**Microorganisms of Cottage, Cream, Neufchatel, and Bakers' cheese.** The desirable organisms in these kinds of cheese are limited to one type. These varieties of cheese are commonly made from pasteurized milk so that the addition of lactic starter to the milk immediately establishes a dominance of the desirable acid-forming and aroma-producing organisms. These bacteria produce the acid required for coagulation and curd making. They constitute the entire normal flora of the cheese. The only other organisms present are those which were able to survive the pasteurizing process and those which may have found their way into the milk or curd by accidental contamination. There is no ripening process in the cheese after making. It is ideal in quality when it is fresh.

**Microorganisms of Cheddar cheese.** This hard, ripened type of cheese is distinguished by the high acidity developed during making. It is the most notable example of a cheese that is salted before it is pressed into its final shape. This time of salting, in conjunction with its acidity, has much to do with the growth sequence of organisms in it during ripening.

Cheddar cheese is made from either raw or pasteurized milk. Lactic starter is used. During the making of the curd, the acid developed is the chief concern of the maker. Only when it has the proper acidity does the milk coagulate to form the characteristic curd (Harding, 1903). This curd subsequently expels its moisture at the correct rate and, at the time of pressing, contains the normal acidity and moisture necessary to establish the conditions for subsequent ripening changes (Hastings, Evans, and Hart, 1912).

The bacteriologists who first studied Cheddar cheese intensively found that acid-forming organisms constituted 99% of the bacterial flora (Russell, 1896; Harding and Prucha, 1908). Kelly (1932) found that of 200 strains of streptococci isolated from Cheddar cheese during the first three weeks of ripening 102 could be classified as *Streptococcus lactis*.

Hastings, Evans and Hart (1912) studied the course of Cheddar ripening and observed that the *S. lactis* types were gradually succeeded by rod shaped organisms. To organisms of this lactobacilli type, Hart, Hastings, Flint and Evans (1914) attributed the formation of flavorful compounds. These bacteria produced some propionic and acetic acids, large amounts of lactic acid and decomposed citric acid in the media they used. Hucker (1922) found lactobacilli as well as *S. lactis* predominating in the better grades of Cheddar cheese. Davis (1935) discussed the factors affecting the sequence of organisms. He suggested that lactate concentration, extent of protein degradation and osmotic pressure are responsible for the gradual crowding out of the streptococci by the lactobacilli.

The addition of lactobacilli to pasteurized milk used for Cheddar has not been entirely successful as a means of controlling ripening. Evans, Hastings and Hart (1914) added *Bacterium casei*, an organism of the lactobaccillus group, to pasteurized milk and observed a sour flavor during the early stages of curing. They believed that these organisms were responsible for the pungent taste of old cheese. Davis, Reardon, and Mattick (1934) observed that the addition of lactobacilli to the milk accelerated protein degradation during the early stages of ripening. Lane and Hammer (1935) added lactobacilli to pasteurized milk with beneficial effects on flavor. Sherwood (1939a, 1939b) found that the lactobacilli might produce either desirable or unpleasant flavors in Cheddar. With careful selections of cultures and light inoculations he made better cheese. Light inoculations (10 ml. to 860 pounds of milk) which added about 12,000 organisms per milliliter of cheese milk were most successful and avoided the production of the sour flavor observed by earlier workers.

McDonald (1945) tried to improve Cheddar cheese by adding *Lactobacillus casei* to the curd rather than to the milk. Flavor changes were most marked, but not uniform, when he added whole milk cultures to the curd. Whey cultures gave better results but commercial applications in this manner were not feasible.

The micrococci probably play a part in the ripening of Cheddar. Harding and Prucha (1908) found them in small numbers in practically all Cheddar. Hastings, Evans and Hart (1912) called attention to the significance placed on organisms of this group by certain European workers, notably Gorini. They found that the cocci dominated the flora of Cheddar at some time or another during ripening. Hart, Hastings, Flint and Evans (1914) observed that the cocci produced large amounts of volatile acids when grown in milk and concluded: "As they (cocci) are present at times in very large numbers in cheese, they, no doubt, produce much of the volatile fatty acids which arise during the ripening process." Hucker (1922) noted that the cocci were equally abundant in both good and poor cheese. Later, Hucker and Marquardt (1926) found that certain strains of acid, proteolytic cocci produced bitter flavors in cheese and that the curd was more rapidly broken down during ripening. They decided that *Streptococcus paracitrovorus* had a decided effect on the production of characteristic flavor in Cheddar but Deane and his co-workers (1915) later observed no benefit when these streptococci were used, but they did obtain encouraging results with an unidentified, "acidoproteolytic coccus." Sherwood and Whitehead (1934) observed that the proteolytic powers of various cultures of streptococci they used as starters had little influence on rate of protein decomposition during ripening. They attributed proteolysis to the rennet enzyme rather than to the organisms themselves.

## UNDESIRABLE MICROORGANISMS

Defects in cheese are frequently caused by undesirable bacteria. These organisms may get into the cheese through the milk supply, contaminated starters, unclean equipment, and the like. Lack of control or improper manipulations during curd making may establish conditions which encourage their growth. There are numerous defects attributable to bacteria in the varieties of cheese under discussion. Only some of the common ones of general significance will be considered here.

**Undesirable microorganisms in Cottage, Cream, Neufchatel, and Bakers' cheese.** The flavor of these soft unripened varieties of cheese should be mildly acid. This flavor is attained by strict control of the quality of the milk and starter. The long period allowed for the development of the proper curd formation encourages the development of all types of organisms that might be in the milk. That is why pasteurization of the milk is regarded as essential for the successful production of this kind of cheese. When microorganisms other than those ordinarily found in the *Streptococcus lactis* type of starter are present in appreciable numbers then the finished cheese can be expected to show objectionable flavors of some sort.

Organisms of the *Escherichia-Aerobacter* group cause objectionable flavors. They may develop enough gas in Cottage cheese before the curd is cut or broken to cause the curd to float in the whey as it is being heated. Gas in the curd, however, may be caused by some of the microorganisms naturally present in the starter itself. Although it may cause the curd to float, such gas development is usually small in volume and is not accompanied by the unclean, unpleasant, sour odor associated with the growth of the organisms of the *Escherichia-Aerobacter* group.

Starters or milk contaminated with yeast organisms cause fermented or yeasty flavors in the freshly made cheese curd.

Soft, unripened types of cheese spoil quickly. Low temperatures that are above freezing are necessary for their protection. The chief organisms causing spoilage are yeasts and molds. They grow on the surface of the cheese despite its acidity. The presence of these organisms in critical numbers on the cheese can be easily detected by characteristic odors. Foter, Anderson and Dowd (1941) studied more than 100 samples of commercial Cottage cheese and found that yeast, the most common cause of spoilage, was sometimes present at the rate of 24 million per gram. Of the total numbers of samples examined, 31% of them were yeasty in flavor.

When yeasts and molds grow on soft, unripened cheese, they reduce the acidity of the cheese. Other organisms soon appear and eventually they usually cause extensive proteolytic decomposition.

**Undesirable microorganisms in Cheddar cheese.** The effects of undesirable organisms may become evident at any time in the making and curing of this variety of cheese. Most defects are detectable early in the life of the cheese. The defects of gas forming organisms are probably most feared. These organisms are usually of the *Escherichia-Aerobacter* group. When they are present in large numbers the effects of their growth can be detected in the odor of the raw milk when it is received at the factory. They may produce enough gas in the curd to cause it to float in the whey. They are indicated in the matting process by the presence of small round holes in the cut surface of a piece of curd. The odor of such a curd is always abnormal. These gas-producing organisms sometimes form round holes in the finished cheese as large as one-quarter inch in diameter. The control of these organisms and their effects is discussed in Chapter 16. Very briefly it can be said that better control of the milk supply, or the starter, and better sanitation on farms or in the factory are essential.

Occasionally lactose fermenting yeasts are the cause of gas in Cheddar cheese. They may be present in the milk supply. This is usually true when farmers are permitted to use the milk cans for hauling whey to stock. Yeasts are sometimes introduced into the cheese by a faulty starter. A yeast defect is an almost certain indication of gross negligence in the handling of milk, starter, or equipment, or all of them.

Rarely gas holes are formed in Cheddar cheese by the action of anaerobic, gas-forming and spore-forming organisms. These organisms are usually indicated when the cheese begins to develop holes and swelling about a week after manufacture. The holes may be irregular in shape, or round and ragged with shining surfaces, or they may be short slits or fissures. The odor of the cheese may be metallic, butyric, or simply unclean. This defect is usually associated with low acidity and low salt content in the finished cheese. It is most frequently observed in cheese made from pasteurized milk.

Color defects caused by microorganisms in cheese have been noted for many years. Harding, Rogers and Smith (1900) found organisms which caused rusty spots in Cheddar cheese. These spots or points seemed to be located on the walls of the small openings in the curd. They appeared in the early months of ripening and were apt to occur most frequently in spring and fall. Davis and Mattick (1929, 1930) and Mattick and Davis (1931) described an organism which caused a similar defect. It was anaerobic and one of the true lactic acid bacteria which was only able to produce the defect under certain favorable conditions. *Pseudomonas fluorescens* was found capable of producing a brownish discoloration in cheese in the presence of potassium nitrate (Harrison, 1929). Pederson and Breed, (1941) attributed the rusty spot defect to two distinct types of lactobacilli which they identified as *L. plantarum* var. *rudensis* and *L. brevis* var. *rudensis.*

Molds which gain entrance into cheese through cracks in the rind cause discoloration of the cheese. This discoloration may appear as a bleached area extending for some distance around the point of actual infection.

**Bacteriophage.** This agent sometimes has such a profound effect on the growth of microorganisms that it seems necessary to mention it at this time.

About 1915 bacteriologists noticed that clear areas sometimes appeared in plate cultures in the midst of bacterial growth. This was apparently caused by some agent which dissolved or disintegrated the bacterial cells. It was thought at first that it might be an ultra-microscopic parasite. Later explanations assumed that it was not a living agent but a protein material with some of the properties of an enzyme. The substance was called **bacteriophage** which denotes "one-that-eats-bacteria." It is commonly called **phage**. There are many bacteriophages. Each phage is so specific in its action that it is usually able to attack only one species of organism or closely related organisms.

Bacteriophage has caused much trouble in New Zealand where its action in the cheese industry has been under investigation since 1928 (Whitehead and Hunter, 1945). The phage problem has been particularly noticed there because the heating of milk for Cheddar manufacture has been widely practiced since about 1920 and because, in more recent years, single strain cultures of acid-forming streptococci have been used for starter. Phage causes sudden stoppage of acid development when single strain cultures are used. When it attacks only one of several strains of acid-forming organisms in the starter or milk then acid development is merely delayed.

Bacteriophage sometimes prevents acid development in the making of soft-unripened cheese. This defect halts the manufacturing operation. When vats of milk so infected are held at the setting temperature they usually resume acid development about 24 hours after inhibition becomes evident. Such lots may eventually develop a typical acidity and produce cheese of fair quality. The renewal of acid development is merely indication that a few of the acid-producing organisms in the milk or starter were not susceptible to the action of the phage present. It is obvious that such renewal of acid development after phage interference cannot be relied upon to complete a manufacturing operation.

In making Cheddar cheese, slow acid production can be regarded as a danger signal. Phage may or may not be responsible, but the need of renewal of starter and greater care in starter management is indicated. Both actions are partial remedies for fighting phage.

The effects of phage action on the making of Cheddar cheese are associated with inadequate acid development. Lack of acid permits undesirable organisms to grow in the milk, curd and cheese. Lack of acid delays firming of the curd, delays enzyme action in the ripening process and prevents the normal sequence of organisms in the cheese.

The problems of bacteriophage in the cheese industry are largely concerned with starters. They are therefore discussed further in this text in Chapter 9.

**Pathogenic organisms and cheese.** Since 1913 several states have passed legislation requiring that milk for cheese be pasteurized, or that the cheese be cured from 60 to 120 days before selling, or that the curd or cheese be pasteurized, that is, processed.

Health records indicate that in the world from 1883 to 1939 there were 42 epidemics traced to cheese. These epidemics included: food poisoning, 28; typhoid, 8; botulism, 2; diarrhea, 2; paratyphoid B, 1; gastroenteritis, 1. Eight of these epidemics were traced to soft-unripened cheese and 17 to Cheddar. Much of the Cheddar concerned was less than 30 days old.

The typhoid fever epidemics of 1944 caused the restrictive legislative actions already mentioned. From 1883 to 1914 in the United States there were no typhoid epidemics traced to cheese. From 1914 to 1943, there were 4 epidemics, 123 cases and 11 deaths. Of these cases, 24 were traced to Cottage cheese and 2 of the victims died. In 1944, when fresh cheese was forced onto the market by price regulations and shortages, there were 80 cases and 2 deaths from typhoid in California and 225 cases and 12 deaths in Indiana. Canada had 80 typhoid cases in this same year. In the period 1932 to 1939, Canada had 6 epidemics, 760 cases and 71 deaths. Many of these were undoubtedly cases of secondary infection.

There is no record in the literature of epidemics of undulant fever, or of septic sore throat traced to cheese, despite the fact that some cheese must be made from milk contaminated with the infectious organisms (Fabian, 1946). Gilman, Dahlberg and Marquardt (1946) inoculated milk with *Brucella abortus* and recovered the organism in Cheddar cheese after 6 months of storage. Naturally contaminated milk gave cheese with the living organisms after 3 months and sometimes longer. Further tests on factory-made cheese discovered no organisms after 41 to 84 days storage at 32°-37°F. although the curd itself had contained the organisms.

Yale and Marquardt (1940) inoculated milk with *Streptococcus pyogenes* and made it into cheese. They decided that the variety of cheese, its moisture content, and the temperatures used for curing were very important in determining the time of survival. The organisms were gone from Cottage 24 hours after making; they survived 28 to 51 days in low-moisture Limburger; in Cheddar they survived 18 weeks at 42°F., but for less than 11 weeks at 62°F.

A holding or ripening period seems to offer some assurance of protection against pathogenic organisms that might be in cheese. It is not infallible. Organisms causing tuberculosis have been found alive in Cheddar cheese after 100 days; typhoid organisms after 3 to 10 months, depending on the temperature of curing; and hemolytic streptococci, after 160 days. The acidity of the cheese and the temperature at which it is stored affect the viability of the undesirable organisms. High acidity and high temperatures are unfavorable to them. Most illnesses attributed to cheese have been traced to the eating of freshly made cheese or curd. This relation seems to justify the belief that aging offers protection.

Brooks (1939), after making a study of milk-borne epidemics over a 22 year period in New York State outside New York City, concluded that most outbreaks originate on the farm. This suggests that preventive measures might be of two types. The first should be pointed to greater care in milk production. Laws requiring protective precautions in producing milk on the farms are found in every state. The Federal Food, Drug, and Cosmetic Act now in force has broad provisions and powers applicable to this situation. Milk producers who are not acquainted with their responsibilities as handlers of food should be educated. But ignorance of the law is no excuse for violations. Strict enforcement of regulations for the protection of the public health should be encouraged and supported by all thoughtful men in the dairy industry.

The second type of preventive measure is pasteurization of milk for cheese. When milk is properly pasteurized by methods and with equipment recommended or approved by health officials, then the cheese made from it should contain no pathogenic organisms from the original milk. It must be remembered, however, that such treatment does not insure the cheese against subsequent contamination from some other source. Here the responsibility rests with those who make, store and sell the cheese.

The healthfulness of the present milk supply of this country is better than it has been in the past. Typhoid fever is at its lowest incidence in our history. Bovine tuberculosis is practically a thing of the past. Bang's disease is being eradicated. The record of cheese as a carrier of pathogens in times past is not faultless but it certainly is *not* one to arouse apprehension for the future.

## REFERENCES

Brooks, P. B. (1939). J. Milk Technol., *2*, 168.
Davis, J. G. (1935). J. Dairy Res., *6*, 175.
Davis, J. G. and Mattick, A. T. R. (1929). J. Dairy Res., *1*, 50.
Davis, J. G. and Mattick, A. T. R. (1930). J. Dairy Res., *1*, 136.
Davis, J. G., Reardon, D. V., and Mattick, A. T. R. (1934). J. Dairy Res., *5*, 144.

Deane, D. D., Anderson, T. G., Warren, F. G. and Dahle, C. (1945). Nat. Butter and Cheese J., *36*, No. 1 : 25.

Evans, A. C., Hastings, E. G., and Hart, E. B. (1914). J. Agr. Res., *2*, 167.

Fabian, F. W. (1946). J. Milk Technol., *9*, 129.

Foter, M. J., Anderson, E. O. and Dowd, L. R. (1941). J. Dairy Sci., *24*, 544.

Gilman, H. L., Dahlberg, A. C. and Marquardt, J. C. (1946). J. Dairy Sci., *29*, 71.

Harding, H. A. (1903). N. Y. (Geneva) Agr. Expt. Sta., Bul. 237.

Harding, H. A. and Prucha, M. J. (1908). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 8.

Harding, H. A., Rogers, L. A. and Smith, G. A. (1900). N. Y. (Geneva) Agr. Expt. Sta., Bul. 183.

Harrison, F. C. (1929). Can. J. Res., *1*, 256.

Hart, E. B., Hastings, E. G., Flint, E. M. and Evans, A. C. (1914). J. Agr. Res., 2, 193.

Hastings, E. G. (1943). Nat. Butter and Cheese J., *34*, No. 10 : 14.

Hastings, E. G., Evans, A. C. and Hart, E. B. (1912). U.S.D.A., Bur. An. Ind., Bul. 150.

Hucker, G. J. (1922). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 90.

Hucker, G. J. and Marquardt, J. C. (1926). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 117.

Kelly, E. D. (1932). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 201.

Lane, C. B. and Hammer, B. W. (1935). Iowa Agr. Expt. Sta., Res. Bul. 183.

Mattick, A. T. R. and Davis, J. G. (1931). J. Dairy Res., *2*, 190.

McDonald, V. R. (1945). J. Dept. Agr. So. Australia, *49*, 2 : 69.

Pederson, C. S., Breed, R. S. (1941). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul: 259.

Russell, H. L. (1896). Wis. Agr. Expt. Sta., 13th Ann. Report pp. 95-111.

Sherwood, I. R. (1939a). J. Dairy Res., *10*, 426.

Sherwood, I. R. (1939b). J. Dairy Res., *10*, 449.

Sherwood, I. R. and Whitehead, H. R. (1934). J. Dairy Res., *5*, 208.

Whitehead, H. R. and Hunter, G. J. E. (1945). J. Dairy Res. *14*, 64.

Yale, M. W. and Marquardt, J. C. (1940). J. Milk Technol., *3*, 326.

# CHAPTER 8

# THE QUALITY OF MILK FOR CHEESE MAKING

The quality of milk is visible in its flavor, odor and appearance. Quality is commonly measured quantitatively by determining bacterial content and sediment or extraneous matter. These properties of milk interest the cheese maker because they affect the characteristics of the finished cheese. The most successful maker must be able to recognize or measure these attributes of milk. He may be required to determine the causes and means of preventing defects in milk quality. It is an accepted fact in the cheese industry that the cheese can be no better than the milk from which it is made.

## Standards

**U. S. Public Health.** Milk is defined in the U. S. Milk Ordinance (1939). There it states in part that milk is the lacteal secretion obtained by the complete milking of one or more healthy cows, excluding that obtained within 15 days before calving and 5 days after calving or for a longer period if that is necessary to produce milk that is practically free of colostrum.

**Food, Drug, and Cosmetic Act.** The Federal Food, Drug and Cosmetic Act (1938) states in section 402: "A food shall be deemed to be adulterated — (a) . . . (3) if it consists in whole or in part of any filthy, putrid, or decomposed substance, or if it is otherwise unfit for food; or (4) if it has been prepared, packed, or held under unsanitary conditions whereby it may have become contaminated with filth, or whereby it may have been rendered injurious to health; or (5) if it is, in whole or in part, the product of a diseased animal . . . (b) (1) If any valuable constituent has been in whole or in part omitted or abstracted therefrom; or (2) if any substance has been substituted wholly or in part therefor; or (3) if damage or inferiority has been concealed in any manner; or (4) if any substance has been added thereto or mixed or packed therewith so as to increase its bulk or weight, or reduce its quality or strength, or make it appear better or of greater value than it is."

This Act is applicable to food shipped in interstate commerce. Milk and cheese are commonly shipped from state to state. The provisions of this Act set standards which the cheese industry as a whole must observe because of the national scope of its operations. The observance of the provisions of this Act must begin on the farms; it does not end until the food product finally reaches the consumer.

**State laws.** State laws usually contain essentially the same minimum provisions for protecting the health and welfare of the consumers within the state. Such laws, regardless of their origin, define minimum conditions of milk production and care. Milk which is produced in conformance to such regulations is safe, wholesome, unadulterated, and normal in physical properties.

**Industrial recommendations.** Industrial requirements for milk quality frequently impose additional standards. These are usually defined in terms of minimum characteristics of flavor, odor, and maximum bacterial content. They may attempt to clarify existing legal requirements by making specific recommendations for the consideration of industrial operators. Such industrial requirements are advisory in character.

Members of the cheese industry belonging to the National Cheese Institute (1947) have prepared a simplified quality code. This code, which cheese factories adopt voluntarily, lists six points to be considered in accepting milk:

"1. **Illegal Milk**

Milk classed as illegal under the laws of the state in which this plant operates will not be accepted.

"2. **Odor and Flavor**

Every can of milk will be examined for odor and flavor and if found to show pronounced objectionable characteristics will not be accepted.

"3. **Sediment**

Each patron's milk will be tested for sediment at least once each week. The bottom-can method of testing will be used as standard. The National Cheese Institute sediment chart will be used as standard.

All milk showing a sediment pad worse than a No. 3, or evidence of mastitis, or *any* extraneous matter of objectionable character will not be accepted.

Patrons delivering milk showing a No. 3 sediment pad will be warned at the time of testing.

"4. **Milk Cans**

Cans used in transporting milk from farm to plant shall be of such construction as to be easily cleaned and must be clean and in good repair.

"5. **New Patrons**

The milk of new patrons must meet the above requirements before being accepted.

"6. **Methylene Blue Test**

It is the recommendation of the National Cheese Institute that each producer's milk be subjected to the Methylene Blue reduction test at least semi-monthly."

## MILK QUALITY AND QUALITY OF CHEESE

The methylene blue test provides a simple means of estimating the bacterial quality of milk. Its bacterial condition is evidence of the care used in producing and handling milk; it is frequently associated with flavor changes in milk. It is not surprising, therefore, to find that the quality of milk indicated by the methylene blue test is associated with the quality of cheese that can be made from such milk.

The relation between quality of milk and cheese is shown in table 8:1. At least 58 of the vat lots of milk should be classified as of inferior quality because the reduction times were less than two hours. Increased reduction times tended to increase the percentages of lots in the higher-scoring classification.

TABLE 8:1. THE PERCENTAGE DISTRIBUTION OF THE GRADES OF CHEESE MADE FROM RAW MILK OF VARYING QUALITY AS INDICATED BY METHYLENE BLUE REDUCTION TIME

(Wilson, Hall and Rogers, 1945)

| *Methylene blue reduction time* | *Number of vats* | *Proportion of cheese in each grade* * | | |
|---|---|---|---|---|
| | | *Score 92 or higher* | *Score 90 to 91.5* | *Score 89.5 or lower* |
| | | % | % | % |
| Less than 1 hr. | 16 | 25 | 6 | 69 |
| 1 to 2 hrs. | 42 | 14 | 48 | 38 |
| 2 hr. or more | 31 | 29 | 61 | 10 |

* Cheese cured 3 months at 34°F.

Further evidence of the relation between quality of milk and cheese was reported by Buck (1932). He made observations at 33 Swiss cheese factories in southern Wisconsin from March through October, 1932. Changes in the average grade of the cheese followed the changes in milk quality; as the milk improved, so did the cheese.

Even when milk is pasteurized to destroy harmful bacteria, the treatment does not remove the effects of their growth in the milk. Price (1927) reported that the quality of pasteurized milk cheese was directly dependent on the quality of the original milk; others have made similar observations (Wilson, Hall, and Rogers, 1945).

These illustrations emphasize that proper care of milk for making cheese must be one of the first concerns of manufacturers interested in the production of clean, wholesome cheese of high quality.

## THE PRODUCTION OF MILK OF HIGH QUALITY

Many conditions contribute to the production of milk of superior quality. Those that are regarded as essential are: healthy, clean cows; proper feeding; good milking technique, whether by hand or by machines; efficient, prompt cooling; use of well-made, sterile utensils; and proper protection from contamination until delivered. These conditions have been concisely described by Jackson and Wallenfeldt (1945).

**Healthy cows.** A competent veterinarian should regularly examine the cows of every milk-producing herd. Bovine tuberculosis and contagious abortion are diseases that have public health and economic significance. Control measures for both of these diseases are being applied on a nation-wide basis. Mastitis is of more importance economically than otherwise. The veterinarian can help in the control of all three diseases.

**Mastitis.** Mastitis in the herd lowers production; in advanced stages it causes milk to be abnormal in flavor, odor and appearance; and it interferes with normal cheese making. Milk from mastitic udders develops acid slowly. Whitehead and Cox (1933) associated this slow acid development with milk that contained in excess of five million leucocytes per milliliter. Leitch (1936) and Prouty (1940) observed that even small amounts of such milk mixed with the regular supply produced a delay in acid development; Prouty was able to measure this effect when the concentration of some samples of the abnormal milk was only 10 per cent of the total. All abnormal milks did not react in this manner.

Price and Roundy (1931) made Cheddar cheese from abnormal milk. They found that acid development was delayed; the curd formed slowly; whey fat losses were increased; yields were less; the body was weaker; and the flavor was not as good as the normal milk produced. Marquardt and Hucker (1937) found that milk from infected udders could be made into satisfactory Cheddar with some special treatments. Johns, Hicks and Gibson (1940) observed decreased yields from milk that was abnormal to biochemical or bacteriological tests; they observed no loss in quality. Johns and Gibson (1941) made a further study of abnormal milk on the yield and quality of Cheddar. They found that differences in yield were practically insignificant; flavors of the cheese made from normal milk were generally superior.

Probably some of the apparent discrepancies between the observations of experimental workers might be reconciled if the degree of abnormality of milks used could be adequately compared. Certainly, if abnormal milk could be eliminated from factory supplies, the cheese industry would benefit.

The control of mastitis is difficult but not impossible. Factors which tend to limit the spread of the infection are: proper milking, frequent examination to detect abnormal udders, removal of badly diseased animals from the herd, milking questionable animals last, and practicing good sanitation in herd management to prevent the spread of the infection.

Most of the tests for detecting abnormal milk require bacteriological skill and knowledge. For a review of such tests and their relative accuracy the student is referred to the work of Fay (1938). These tests, in general, cannot be applied effectively to the mixed milk of the herd. The daily use of the strip cup by the farmer is generally regarded as one of the best means available in farm practice for detecting udder troubles promptly.

**Clean cows.** Ayers, Cook, and Clemmer (1918) listed four factors in producing clean milk of low bacterial content; they were: clean cows, small-topped milk pails, sterile utensils, and prompt, efficient cooling. To keep cows clean, the udders and flanks should be clipped. Cows should be groomed properly. Just before milking the cow's udder and teats should be wiped carefully with a clean cloth wrung out in warm (130 F.) water and chlorine solution. This treatment cleans the surfaces which will touch the cups of the milking machine; it cleans the milker's hands; it disinfects the udder surfaces and so helps control udder infections; and, finally, it stimulates milk flow and thus helps to shorten the milking operation. A fresh, clean cloth should be used for each animal.

The cow barn affects the cleanliness of the cow and the milk she produces. The barn should be clean, well-lighted, and ventilated. Desirable barns will have tight ceilings and walls, waterproof floors, and screen doors and windows. The use of plenty of bedding under the cows, prompt removal of manure, and liming of the stable floor, are means of maintaining sanitary conditions. Such undesirable odors as may come from feeds, manure, or other livestock detract from the cleanliness of the barn and may actually produce off-flavors in the milk, according to Petersen and Brereton (1942).

**Proper feeding.** Silage, sweet clover, and alfalfa, when eaten by cows shortly before milking, may impart their characteristic flavors to the milk In a like manner, other feeds with strong flavors may injure the quality of the milk for cheese making. Among such foods can be listed: onions, garlic, rape, turnips, leeks, cabbages, ragweed, bitterweed, and the like. Even the flavor of green grass pasture in the spring of the year can be found in the milk. Babcock (1938) reviewed the problem of feed flavors in milk and milk products. In his summary he pointed out that the intensity of the off-flavors varies with the feed, quantity consumed, and interval between feeding and milking. These flavors commonly enter the milk through the body of the cow and appear in the milk only for a few hours after feeding.

**Utensils.** Furna (1942) reported that the three principal causes of rejected milk were improper cooling, dirty utensils, and mastitis.

Keeping utensils in proper condition to handle milk depends upon their construction, and the methods used in cleaning and sterilizing. Well-made utensils have smooth surfaces and rounded corners. Utensils with rusty spots and open seams are unfit for milk handling. The best utensils are well-tinned or stainless steel.

Milk utensils should be cleaned immediately after they are used to prevent the drying of milk solids on the surfaces of the utensils. The cleaning procedures can be summarized briefly:

(1) Rinse with luke warm or cool water.

(2) Scrub with a brush using warm (120° F.) water containing a dairy cleanser, not soap.
(3) Rinse with warm water.
(4) Scald with hot water and shake off drops to hasten drying.
(5) Place utensils upside down on a clean rack to dry.

Wetting agents may be used successfully. Milkstone removers contain acid and should be rinsed from tinned utensils very thoroughly to prevent corrosion.

Milk utensils should be sterilized immediately before they are used. Chemical sterilization is most practical under farm conditions. To be effective, the sterilizer should be used only on clean utensils. Chlorine sterilizers have been used successfully in this manner for many years. The U. S. Public Health Service (1939) recommends exposure for two minutes to a solution containing 100 parts per million of active chlorine. Quaternary ammonium compounds may also be used. The small amounts of chlorine solution remaining on the utensils will not harm the properties of the milk providing the treatment takes place just before the utensils are used.

Milking machines have always been a problem in the cheese industry. They are highly specialized utensils that require careful attention because so many parts of the machine cannot be inspected easily. The same general procedures described for cleaning utensils apply in cleaning milking machines. The machines must be taken apart so that every part which milk might have touched can be scrubbed. The teat cup assembly, after it has been washed, can best be cared for by placing on a rack where it can be filled with a one-half per cent lye solution. Just before milking, the lye is discarded and the assembly is rinsed by drawing chlorine solution through the cups and into the machine itself. Lye must not be used on machines where it may touch aluminum parts. Detailed instructions for cleaning their own milking machines should be obtained from the manufacturers.

Milking machines create no problems in the cheese industry if they are kept clean and are used properly. Better milking practices with machines, such as those described by Smith and Werner (1945) and Hopson, Lindsey and Braddock (1945), actually protect the health of the cow and produce milk of highest quality.

**Milking technique.** The best milking technique removes milk from the udders quickly and completely, maintains healthy udders, protects milk against contamination, and produces maximum yields of milk and milk fat. Milking cows by machine has been systematized and the system is being generally applied with great success. The essential steps as described by Smith and Werner (1945), are:

(1) Wipe off the cow's udder with a clean cloth wrung out in warm (130 F.) water containing 250 parts per million of chlorine. Use an individual cloth for each cow.
(2) Draw a few streams of milk from each quarter into a strip cup to stimulate "let-down" and to detect abnormal milk.
(3) Attach the teat cups within a minute or two after steps (1) and (2).
(4) Time the operation of milking. Most cows will milk out in 3 to 4 minutes.
(5) As soon as milk stops flowing, pull down on the teat cups with one hand and massage the udder with the other hand to strip out the last milk in the udder.

It is important to dip the teat cup assembly into a pail of clean water and then into a 250 p.p.m. chlorine solution before each cow is milked. The pails of water and chlorine solution will have to be changed after milking about a dozen cows. This treatment protects the cows from infection and keeps the teat cup assembly clean.

If cows are milked by hand, the cow should be prepared as in steps (1) and (2) described for machine milking. Dry-hand milking is essential for the production of milk of high quality. Milkers must be healthy, should have clean hands, and should have no sores on hands or arms. Small-top milk pails are best. They are just as easy to use and to clean as the others. Milk stools should be as clean as the milkers' hands.

**Straining milk.** Straining of milk improves its appearance but does not improve its quality from the bacteriological standpoint. Straining only removes the coarser particles of insoluble material. It is better practice to keep extraneous material out of milk by maintaining clean barns, clean cows, insect-free premises, and keeping milk covered at all times.

Mechanical strainers should be easy to take apart and clean. They should protect the strainer disc against direct impact of the milk poured into them. Single service cotton discs should be used and they should be discarded immediately after use.

Used discs are dangerous sources of bacterial infection for milk to be used for cheese.

**Cooling.** Cooling is the effective way to prevent the growth of bacteria in milk. Prompt cooling to low temperatures is necessary for best results. Frayer (1932) found that cooling milk promptly to 50° F. was a fairly satisfactory procedure even when it was held overnight. Cooling morning's milk to 60° F. immediately was fairly satisfactory but was unsatisfactory for evening milk. Cooling to 40° F. and holding at that temperature produced the best results. The longer cooling was delayed, the worse was the resulting milk after 24 hours. Cooling to 40° F. or below is recommended.

Mechanically refrigerated cooling tanks are coming into more common use. A good milk cooling tank, such as can be constructed on the farm, should provide about three times as much water as there is milk to be cooled. Such a tank should have an insulated cover and a drain to empty it when necessary. When well water is used for cooling, the tank should be emptied daily during the warm months.

When ice or mechanical refrigeration is used, it is not necessary to stir the milk while it is cooling, providing the ice-water is below 40° F. If milk must be stirred, then only a clean, sterile agitator should be used.

Warm milk should not be mixed with cold milk.

**Protecting milk.** The milk must be carefully protected after it is produced. The first desirable facility for this purpose is the milk house. If it is well-planned it will have an adequate supply of hot and cold water, a place to wash, sterilize, and store utensils, and proper storage facilities for the milk while it remains on the farm. The construction of the milk house should provide a clean room with water-proof, well-drained floors, tight, smooth walls and ceilings, good light and ventilation. It should be constructed so that it will provide a comfortable place to work in every season.

The second important facility for protecting the milk is an enclosed truck for transporting it from the farm to the factory. Such trucks should protect the milk from excessive heat and cold as well as from contamination from road dust. Trucks used for hauling milk must not be used for hauling anything which might contaminate the outside of cans. Trucks should be kept clean by scrubbing and chlorine disinfection at suitable intervals to keep them in sanitary condition at all times.

A third facility for producing better milk is the "milking parlor." There is a growing trend in the milk industry to provide a small area equipped with every convenience for milking. The milking parlor is a relatively small, well-lighted room in which the cows, singly or in small groups, are held only during the milking interval. Grain is commonly fed to the cows in the milking parlor but that is all. When this area is available, the conventional stable or barn becomes merely a place where the cows are housed and fed. Often the animals are not confined to stanchions. According to Bendixen and Smith (1945), milking parlors have in most instances decreased the investment, improved working conditions, and provided higher standards of sanitation in the production of milk.

## COMMON TESTS FOR APPRAISING QUALITY OF MILK FOR CHEESE MAKING

Tests commonly applied to determine the quality of milk when it is delivered to cheese factories are: flavor and odor, appearance or visible sediment, methylene blue test, fermentation test, acid test, and Wisconsin curd test. Other tests are occasionally applied; these include, bacterial counts—either microscopic or plate counts, and the resazurin test.

The phosphatase test is only applied to milk which has been heated. This test indicates whether the heat treatment was sufficient to destroy the milk enzyme, phosphatase. It is not a test for milk quality. It is fast becoming an important test in factories where pasteurized-milk cheese is made and sold as such. Laws of several states already require pasteurizing treatments and it seems probable that within a short time federal laws will have similar specifications for many common varieties of cheese. Factories will have to apply this phosphatase test to the heated milk to be certain that it is pasteurized.

**Flavor and odor test.** Ideal, whole milk is slightly sweet to the taste, odorless, and without any lingering flavor. The "richness" of whole milk feels pleasantly smooth in the mouth, but this sensation cannot properly be classified as flavor.

The flavor of milk is determined at the milk-intake by the "nose" test. The value of a trained individual to inspect incoming milk by its odor cannot be overrated in any quality control program. The milk can be examined quickly and effectively. Inferior milk can be detected and rejected promptly before it can do any harm.

The operator who judges the odor and taste of the milk at the receiving platform should remove the cover from the can himself and should smell of the cover and the contents of the can immediately. The odor of the milk is a better means of judging quality than taste, especially when many samples must be examined in a limited period of time. Trout (1946) found that it took approximately 7.2 seconds to identify flavors in the milk by tasting in the mouth. Inferior milk can be detected easily by its odor alone. Many times the causes of the faults can be identified at the same time. Odors attributable to feeds, unclean utensils, lack of cooling, and acid development, are among those easily identified. Furna (1912) found that skillful judges of incoming milk could nearly always detect by their odor the presence of milk with high bacterial counts and the effects of mastitis.

Off-flavors and odors in milk are not only indicative of faulty handling of the product but are directly related to the flavor of the finished cheese. When the flavor is one that may have been absorbed by the milk or caused by feed, it may be more pronounced in the finished cheese. Flavors that are absorbed by the fat in the milk are of this class. Flavors that are indicative of bacterial action will also be more intense in the finished cheese but, in addition, they may be further exaggerated by the growth of the causal organisms during the manufacturing and curing operations.

The aeration of milk during pasteurizing with certain types of machines undoubtedly removes some odors. Robichaux and Wilster (1941) observed that a vacuum pasteurizer (Vacreator) removed strong feed and oxidized flavors apparent in the raw milk; the flavors could not be detected in the cheese. Trout (1944), in commenting on aeration (without vacuum treatment) stated that, at best, it only minimized the effects of faulty milk production. He argued that prevention of the defects was the better cure.

**Sediment test.** Ideal milk contains no extraneous matter; when it is received at the factory it should appear clean.

The sediment test is used to detect the presence of some types of insoluble material. It is the test best adapted to the first primitive steps in improvement of a milk supply. It may be used to teach the producer the necessity of preventing contamination of the milk. As a measure of real quality, however, it has no value. It does not distinguish between milk that is really clean and that which has been "cleaned."

The sediment test should be used only in conjunction with tests for bacterial quality. "Cleaned" milk can be of low quality bacteriologically and at the same time have an excellent sediment test. Weckel (1911) enumerated four important sources of sediment in milk: dirty flanks and udders, wet and dirty hand milking, dirt in utensils and cans, dirt gathered from dust in the barn, milkhouse, roadside stand, or truck. It is easy to see how such sources can contribute largely to the bacterial content of the milk even though the insoluble portions may be removed by filtration and be undetected by the sediment test.

Samples of milk for sediment tests are commonly taken from the bottoms of the cans before the milk is accepted at the factory. A special tester which reaches to the bottom of the can is used for this purpose. Obviously, this does not give a representative sample. Excluded from such samples are particles of sediment that tend to float; rodent hair is an important example.

Samples of milk for sediment tests are also taken from the cans after thorough agitation; they are sometimes taken from the weighing can after all cans of the patron's milk have been mixed together. The latter practice does not permit the convenient rejection of the milk if it is unacceptable.

The results of the sediment test can be highly variable depending on several factors. The method of sampling the milk is only one of these factors. Others to be considered are: the color of the sediment, the density of the sediment, the type of filter pad, and the quality of the filter pad.

### *Sediment Test for Cheese Factory Practice*

*Sampling.* The sample of milk taken from the bottom of the can without previous stirring of the milk is most commonly used in quality improvement work. It is the sample usually taken by law enforcement officials. It is generally recommended for inspection of cheese-factory milk supplies.

*Apparatus and materials.* The off-the-bottom sample requires a tubular tester or sampler which will reach to the bottom of the can. These testers are operated either by hand or by air pressure. When a sampler is used to remove the milk to be tested, then a sediment filter is provided. Additional materials include cotton discs, individual cards for mounting discs, and sediment disc standards or photographs of them. The materials and equipment can be obtained from dairy supply dealers; the photographs of standards can be obtained from the American Public Health Association, 1790 Broadway, New York 19, N. Y. and the National Cheese Institute, Inc., 110 N. Franklin St., Chicago, Ill.

*Procedure for Making Sediment Test:*

1. Draw a one-pint sample of milk off the bottom of the can by moving the tester or sampler across the center of the can from one side to the other. The suction end of the tester or sampler should be not more than one-quarter of an inch above the bottom of the can.

2. Filter the milk through the disc in the sediment tester. Remove the disc from the tester and mount it while it is still moist on the individual card.

3. Label the disc to identify the source of the sample and to indicate the amount and nature of floating extraneous material not present on the disc.

4. Dry the disc, if it is to be preserved for subsequent use. The disc can be classified by visual inspection according to the existing standards when it is either wet or dry.

*Interpretation.* Milk with excessive amounts of dirt or with critical material, such as insect fragments or hairs, is unacceptable. Amounts of visible dirt which must be described as "excessive" can be determined by comparing the discs with prepared standards or with photographs of standards which can be obtained from most dairy law enforcement agencies.

*Dipper strainer for sediment observation.* Sediment in milk is being estimated by some sanitarians by using a 100-mesh dipper strainer. It is used particularly for the detection of flakes of material in the milk. Flakes of fat can be distinguished from flakes of curd by immersing the dipper and the contents in hot water. Curd particles which are insoluble in hot water, indicate milk from diseased udders. Particles of fat are caused by improper handling of milk, such as slow cooling, and mixing warm and cold milk together. This application of the strainer dipper, according to Brueckner (1913), justifies its use more generally.

**Methylene blue test.** The methylene blue test for quality of milk for cheese factory use is practical, inexpensive, and excellent for measuring milk quality. The results of the test cannot be obtained quickly enough to make it the basis of accepting milk at the weighing stand at the time of delivery. Its function is to identify the producers of milk of satisfactory quality. It serves as a basis of action for farm inspection, education, and quality control.

The test takes its name from the dye used in performing it. The dye colors the milk blue. The color disappears quickly if there are many bacteria in the milk and more slowly with fewer organisms. Milk in which the development of acid is detectable by its odor may decolorize within 2 or 3 minutes after the dye is added. Milk of excellent bacteriological quality may remain blue for 8 hours or more. The blue color of the dye persists as long as oxygen is present in the milk. Growing bacteria use up oxygen and, to a limited extent, the milk constituents also combine with oxygen. Milk which decolorizes after 6 hours, according to Hastings (1941), owes its color change chiefly to the constituents of the milk rather than to the bacteria.

Occasionally wide differences may be observed in the time required to decolorize identical samples of milk. Thornton and Hastings (1930) showed that any agitation of the tubes which prevented the rising of fat made the results more uniform and somewhat shortened the time of reduction. Evidently the bacteria of the milk tended to accumulate in the cream layer. Inversion of the methylene blue tubes at periodical intervals has received general approval of investigators (Frayer, 1937; Johns, 1938). Hastings (1941) suggested that the tubes be inverted after each interval of observation. Johns (1939) reported that mixing at two hour intervals gave results that agreed well with more frequent agitation.

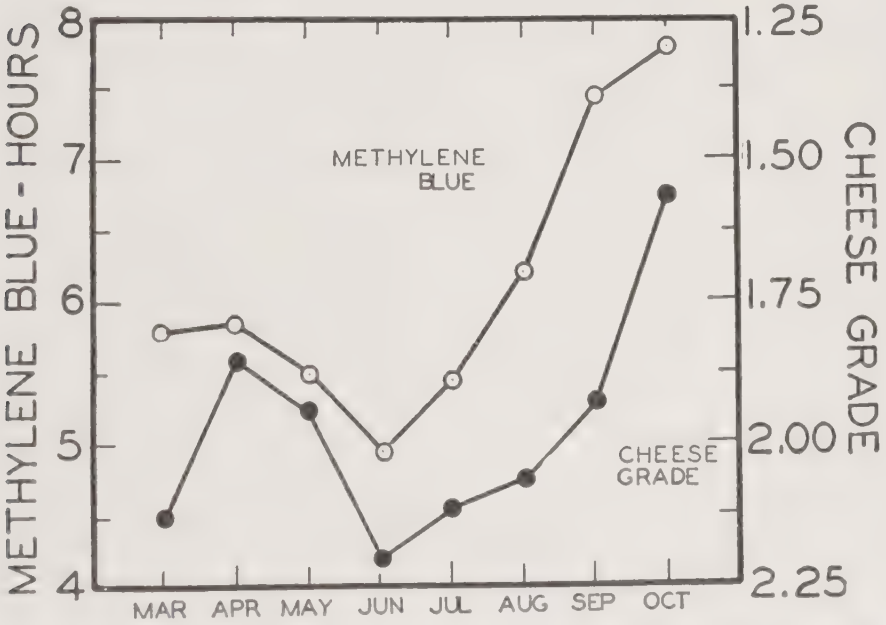


Figure 8-1. The average grades by months of all cheese produced in 33 factories show the same general trends as the average of methylene blue tests; the best milk tends to make the best cheese. (*Unpublished data collected by Charles A. Buck, extension specialist, University of Wisconsin*).

The methylene blue test has a special significance in cheese making because it is influenced directly by the growth of organisms in the milk. Excessive numbers of growing organisms, indicated by short decolorizing times, reduce the chances of controlling the manufacturing and curing operations. Table 8:1 and figure 8:1 both show the effects on cheese quality of using milk of varying methylene blue tests.

The methylene blue test is reliable, simple to use, and inexpensive to own and operate. The results of the test are directly associated with properties of the milk that affect the economy of factory operation and the quality of the finished product. By its frequent use a factory operator can classify milk producers into groups according to the desirability of the milk they deliver. Such a classification simplifies milk quality control work because it indicates where the least effort should produce maximum benefits.

The Sub-Committee on Cheese Quality of the Manufacturing Section of the American Dairy Science Association submitted a report on the use of the methylene blue test in cheese factory practice. The report was accepted by the Manufacturing Section of the American Dairy Science Association (1941), but was not published. Committee members who prepared the report were: E. F. Goss, F. E. Hanson, C. A. Phillips, W. V. Price, E. L. Reichart, Z. D. Roundy, W. H. Sproule, S. L. Tuckey, H. L. Wilson, and M. W. Yale. Their essential instructions are reproduced here:

### *Methylene Blue Test for Cheese Factory Practice*

*Apparatus and materials.* Apparatus and materials include: 10 ml. dipper; 100 ml. graduate cylinder; 1 mark, 1 ml. capacity pipette, or a burette with 1 ml. graduations; thermometer; test tubes, 150 mm. long by 12-15 mm. diameter, etched at the top to permit labeling with a lead pencil; 200 ml. bottle with stopper to hold methylene blue solution; rubber stoppers to fit the tubes (optional); water bath incubator, thermostatically controlled to hold samples between 98° and 99° F.; racks to hold tubes, preferably rust resistant; methylene blue tablets, (methylene blue thiocyanate) certified by Commission on Standardization of Biological Stains, obtainable from dairy supply organizations.

*Methylene blue solution.* The methylene blue solution is made by dissolving 1 methylene blue tablet by letting it stand in 200 ml. of water overnight. Sterile or freshly boiled, distilled water or freshly boiled, clean, drinking water is used. The tablet must be entirely dissolved before the solution is used. The solution is only used for one week.

*Sampling milk for methylene blue test.* Sample the milk by mixing it vigorously just before sampling and then transfer a 10 ml. portion with the dipper to the test tube in which the test is to be made. Pouring the milk from the cans into the weighing can is regarded as adequate mixing. Rinse the sampling dipper in clean, cold water immediately after using, and rinse it thoroughly again in the milk itself before the next sample is taken.

Number the tube to identify the sample, and store it with other similar samples in ice water for a period of not more than two hours before starting their incubation. When they are held in this manner, complete sets of samples can be assembled and incubation of all of them can be started at one time.

## *Procedure for Methylene Blue Test*

1. Measure out 1 ml. of methylene blue solution and add it to 10 ml. sample of milk in test tube. If samples can be collected quickly, the dye can be measured into the tubes ahead of time and the samples need not be cooled before incubation begins.

2. Stopper the tubes and place them in the 98°-99°F. water bath for five minutes. Invert the tubes once after five minutes. Be careful to hold the stoppers on the tubes when inverting at this time for the increasing pressure in the warm tubes may blow them out. If the dye solution is first measured into the tubes and the milk sample is then poured into it, the dye will be evenly distributed without shaking and without inverting the tubes.

3. The methylene blue reduction time is the interval between placing the tubes in the 98° F. water and the disappearance of the blue color from the milk. The longer it takes for the milk to return to its original white color, the fewer bacteria it contains.

4. Observe the tubes of milk at suitable intervals and record the identity of samples which have turned white. Intervals recommended for examination of samples are at 1, 3, and 5 hours after warming the tubes to 98°F.

5. Invert each rack of samples after each examination period. Do not shake the tubes because it incorporates oxygen and prolongs the reduction time.

STANDARDS OF QUALITY

| *Grade* | *Quality* | *Methylene blue test* |
|---|---|---|
| A | Good | Decolorizes in more than 5 hours. |
| B | Fair | Decolorizes in less than 5 but more than 3 hours. |
| C | Poor | Decolorizes in less than 3 but more than 1 hour. |
| Under Grade | Unacceptable | Decolorizes in less than 1 hour. |

*Precautions to observe*

1. Use glassware which is scrupulously clean.

2. Sterilize the containers for dye solution, the pipettes, test tubes, and rubber stoppers, if possible. If this is impossible, boil the glassware and stoppers immediately before use and allow the retained heat to dry the equipment.

3. Do not put the tubes in the water bath in such large numbers at any one time to delay the warming period more than 5 minutes.

4. If a 98° F. air-type incubator is used in place of a water bath, place the samples in water at 98° F. for 5 minutes before putting them in the air incubator.

5. Do not hold the dye solution more than one week.

**Resazurin test.** The resazurin test, which has not been used extensively in the cheese industry, is based on the use of another dye like methylene blue. The dye gives the milk a slate blue color which changes during the incubation period to pink and finally to white. The change from slate blue to pink may be caused by conditions other than bacterial growth. Johns and Howson (1940a) observed that resazurin tests on identical milk took about three-fourths of the time to reach the pink stage that methylene blue took to change from blue to white.

Johns (1941, 1942) and Ramsdell, Johnson and Evans (1935) concluded that resazurin is just as sensitive to bacterial activity in milk as methylene blue; and it is more sensitive to abnormal milk, such as mastitis milk, colostrum milk and milk of late lactation. Frayer (1942) regarded the sensitivity of resazurin to factors other than bacterial content as a possible handicap. He argued that, without microscopic examination to verify the findings of the resazurin test, the methylene blue test was likely to give better results in the average milk plant.

*Procedure.* The general instructions for making the methylene blue test are followed in respect to collection of samples, sterilization, and handling of glassware and equipment.

Resazurin tablets certified by the Commission on Standardization of Biological Stains can be obtained from any reliable dairy supply company. These tablets are usually of such strength that one tablet dissolved according to instructions in 200 ml. of sterile water, will keep for one week if it is stored in the dark in a dark bottle.

Dye solution is mixed with the milk at the rate of 1 ml. of solution to 10 ml. of milk.

The tubes are stoppered, labeled, and incubated at 37°C. (98.6°F.) in the same manner as has been described for the methylene blue test.

*Interpretation.* Johns and Howson (1940b) recommended a simple routine grading system based upon the time required by the incubated sample to undergo a definite color change. They recommended the standard color number 8 described as P 7/4 according to the Munsell system of color identification. This color standard can be obtained from the Munsell Color Company, Baltimore, Md. All samples which exceed the number 8 standard in 1 hour are 4th grade; those showing the change in 2 hours are 3rd grade; those which do so in 3 hours are 2nd grade; and those that have not reduced beyond the color standard in 3 hours are placed in the 1st grade. They suggested that the use of a daylight lamp is important for judging the colors and recommended a 15 watt Mazda fluorescent daylight lamp with a neutral grey background.

Ramsdell, Johnson and Evans (1935) suggested several interpretations of observed color changes: (1) Rapid reduction beginning at once or soon after the start of incubation might be caused by high contamination with actively growing or strongly reducing microorganisms, or by pathological (diseased udders) or physiological (colostrum, late lactation) abnormalities. (2) Slow reduction, over 4 to 6 hours of incubation might be attributed to few organisms or inactive organisms, or to weakly reducing organisms, or to low cell count. (3) Slow reduction followed by rapid reduction of color might signify physiologically and pathologically normal milk, low bacterial count, or high count with organisms in the lag phase. (4) Rapid reduction followed by slow reduction might be caused by physiologically and pathologically abnormal milk, large numbers of bacteria with low reducing powers during active growth, or old milk in which some growth had occurred.

**Fermentation test.** This test is commonly made by holding the tubes of the methylene blue test overnight at 98°F. The results of the test are interpreted as desirable or undesirable depending upon the odor and appearance of the curd that is usually formed in this incubation period. A smooth, solid curd with a mild, acid odor is said to be desirable; a gassy, wheyed-off, or digested curd is said to be undesirable.

This form of fermentation test is of questionable value and, under some circumstances, it may actually be misleading in a quality improvement program.

Milk of high quality has a low bacterial content and will remain blue in the methylene blue test for 6 hours or longer. Such milk quite commonly shows a partly digested or even gassy curd in the fermentation test. On the other hand, milk which is inferior by bacterial count and methylene blue tests may produce a solid curd and acid odor in the fermentation test. The apparent contradiction of these tests is more apparent than real. Hastings (1941) pointed out that the results of the fermentation test are determined by the ratio of types of organisms in the milk. The quality of the cheese depends upon *numbers* of active organisms. The bacterial activity of milk with low bacterial content and favorable methylene blue test can be easily and positively controlled by the normal inoculation of desirable starter. This suggests a more desirable form of fermentation test.

Some technicians are making fermentation tests by adding to each measured quantity of milk in the fermentation tube the same proportion of starter as is used in making the cheese. The required amount of fresh, active starter is added to each tube at the beginning of the fermentation period. For example: if starter is added to the vat at the rate of 1 per cent, then 10 ml. of milk in the fermentation tube will require 0.1 ml. of starter. This small amount of starter is conveniently measured by mixing 1 part of starter with 9 parts of sterile water and using 1 ml. of the mixture for inoculating the 10 ml. of milk in the fermentation test. One or two tubes of sterile milk should be similarly inoculated with diluted starter and incubated with the tubes of milk to be tested.

The tubes of inoculated sterile milk will show a desirable curd formation after a 24 hour incubation period at 98° F. if the starter is of satisfactory quality. All other tubes of milk under test will likewise show desirable curd characteristics if the milk is of satisfactory quality.

Even this modification of the fermentation test is unreliable if the original milk reduces in less than 3 hours on the methylene blue test. Milk which reduces too rapidly in the methylene blue test contains so many organisms that the manufacturer may experience difficulty in controlling the making operation. Such milk usually contains undesirable flavors and odors which eventually injure the quality of the cheese.

**Wisconsin curd test.** This test is essentially a modified form of the fermentation test; it is intended to determine the nature of the types of organisms in milk. Like the fermentation test it may be misleading in judging the quality of milk unless it is used in conjunction with the methylene blue test or another measure of the bacterial content of the milk.

Pint jars are commonly used to hold the milk in making the test. They are sterilized by boiling in water and are filled with the milk to be tested. These jars are covered and are heated in warm water to a temperature of 90° F. A few drops of rennet solution are added so that the milk coagulates in 10 to 15 minutes. The curd which is formed holds the gas which may be produced in the early stages of fermentation. (This gas escapes in the fermentation test by diffusing through the liquid before the acidity alone can cause coagulation of the sample.) The curd is cut with a sterile knife and the whey which separates is poured off from time to time. The small round piece of curd which remains is held at 90° to 98° F. for 12 to 16 hours and then examined. Each curd is cut in half for inspection.

Smooth, solid surfaces and a clean, mild acid flavor and aroma usually indicate a desirable milk. Rough, spongy or slimy curd with numerous gas holes and an unpleasant flavor indicates the presence of undesirable types of organisms in the milk.

The test may be modified by the addition of 5 ml. of starter to the pint of milk normally used. If the results of the modified test are unfavorable, it is an indication that the organisms of the milk supply cannot be controlled by the addition of normal amounts of starter. The starter itself might cause gas formation in the modified test. This is highly unlikely if seed starter, used for inoculating the test, is active and shows no gas formation in its glass containers.

**Acid test.** This test is of great value to control manufacturing processes but it is a poor measure of milk quality. Individual cows produce normal, fresh milks which may titrate from approximately 0.12% to 0.25%. The titratable acidity of mixed milks of herds of cows is less variable but commonly ranges from 0.11% to 0.23%. These variations are directly related to certain constituents of milk, according to Rice and Markley (1924). These constituents are carbon dioxide, citrates, casein, albumin, and phosphates. The alkali combining capacity of the milk is only in part an indication of the lactic acid which may have been developed by the fermentation of lactose. It becomes evident that, before associating any certain level of acidity with the results of bacterial activity, it would be necessary to know the titratable acidity values of fresh milk.

The test is not as sensitive an indication of bacterial activity as the methylene blue test. As a matter of fact, most trained operators can detect the effects of bacterial activity by sense of smell before they can be measured with certainty by titration.

**Other tests.** The tests that have been considered are those most commonly used in factory practice. Other tests are also used where laboratory facilities and trained personnel are available.

The *microscopic count* of numbers of organisms in milk is particularly useful when it can be applied in evaluating the quality of a milk supply. Numbers of organisms indicate the level of quality. Presence of such signs as leucocytes in excessive numbers, clumps of bacteria, long chains of streptococci, and the like, indicate the causes of inferior quality to the trained observer.

The *plate culture method* of examining milk for bacteriological quality can be applied to milk for cheese making as well as to milk for other uses. It can be most advantageously applied where the facilities of a bacteriological laboratory are available. Much time is required to take samples, prepare dilutions, "pour" plates, incubate plates, and interpret the results. The microscopic count is usually preferred by those sanitarians, especially fieldmen, who feel that observations must be the basis of action rather than record.

The plate culture method provides a means of careful analysis of types of organisms which may be disclosed by special techniques. In this manner, highly specialized laboratories identify and count specific organisms, like *Escherichia coli*, which might cause defects in cheese or which might be regarded as indicative of undesirable sanitary conditions of production. Such refinements can always be applied in well-equipped factories. It is questionable whether the expense could be justified with a milk intake of less than 100,000 pounds per day to be made into Cheddar cheese. On the other hand, smaller factories might be able to afford such laboratory facilities when engaged in the production of the fancy types of cheese.

## REFERENCES

American Dairy Science Asso. (1941). 36th Annual meeting, June 1941. Report of sub-committee on cheese quality. J. Dairy Sci., *24,* 740-752.

Ayers, S. H., Cook, L. B. and Clemmer, P. W. (1918). U. S. Dept. Agr., Bul. 642.

Babcock, C. J. (1938). J. Dairy Sci., *21,* 661.

Bendixen, H. A. and Smith, L. J. (1945). Wash. Agr. Expt. Sta., Bul. 461.

Brueckner, H. J., (1943). Am. Milk Rev., *5,* No. 1: 10.

Buck, Charles A. (1932). Ann. report for 1932 to the Director of Wis. Agr. Expt. Sta., (Unpublished data).

Fay, A. C. (1938). J. Milk Technol., *1,* 38.

Federal Food, Drug and Cosmetic Act (1938). Public No. 717 75th Congress, Chap. 675—3rd Session, S. S. Approved, June 25, 1938.

Frayer, J. M. (1932). Vt. Agr. Expt. Sta., Bul. 343.

Frayer, J. M. (1937). Vt. Agr. Expt. Sta., Bul. 424.

Frayer, J. M. (1942). Vt. Agr. Expt. Sta., Bul. 498.

Furna, R. L. (1942). 16th Ann. Report, N. Y. State Assoc. of Milk Sanitarians. p. 121.

Hastings, E. G. (1941). Ext. Service, Coll. of Agr., Univ. Wis., Circ. 316.

Hopson, George H., Lindsey, K. J., and Braddock, Thomas (1945). J. Milk Technol., *8,* 205.

Jackson, H. C., and Wallenfeldt, E. (1945). Ext. Service, Coll. of Agr., Univ. Wis., Circ. 356.

Johns, C. K. (1938). J. Dairy Sci., *21,* 227.

Johns, C. K. (1939). Am. J. Public Health, *29,* 239.

Johns, C. K. (1941). 15th Ann. Report of N. Y. State Assoc. Dairy and Milk Inspectors, p. 173.

Johns, C. K. (1942). Can. J. Res., *20,* 336.

Johns, C. K. and Gibson, C. A. (1944). J. Dairy Res., *13,* 287.

Johns, C. K., Hicks, T. J., and Gibson, C. A. (1940). J. Dairy Res., *11,* 298.

Johns, C. K. and Howson, R. K. (1940a). J. Dairy Sci., *23,* 295.

Johns, C. K. and Howson, R. K. (1940b). J. Milk Technol. *3,* 320.

Leitch, Renwick H. (1936). Scottish Jr. of Agr., *19,* 343.

Marquardt, J. C. and Hucker, G. J. (1937). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 242.

National Cheese Institute (1947). National Cheese Institute, Inc., 110 N. Franklin St., Chicago, Ill.

Petersen, W. E. and Brereton, J. G. (1942). J. Dairy Sci., *25,* 381.

Price, W. V. (1927). N. Y. Agr. Expt. Sta., Cornell Univ., Memoir 105.

Price, W. V. and Roundy, Z. D. (1934). National Butter and Cheese J., *25,* No. 19:24.

Prouty, C. C. (1940). J. Dairy Sci., *23,* 899.

Ramsdell, G. A., Johnson, W. T., Jr., and Evans, F. R. (1935). J. Dairy Sci., *18,* 705.

Rice, Frank E. and Markley, Alton L. (1924). J. Dairy Sci., *7,* 468.

Robichaux, R. P., and Wilster, G. H. (1941). Proc. 27th Ann. meeting Western Div., Am. Dairy Sci. Assoc., p. 62.

Smith, Vearl R. and Werner, Geo. M. (1945). Ext. Ser., Coll. of Agr., Univ. of Wis., Spec. Circ., January.

Thornton, H. R. and Hastings, E. G. (1930). J. Dairy Sci., *13,* 221.
Trout, G. M. (1944). Milk Plant Monthly, *33,* No. 10:22.
Trout, G. M. (1946). J. Dairy Sci., *29,* 415.
U. S. Public Health Service (1939). Public Health Bul. 220.
Weckel, K. G. (1944). Milk Plant Monthly, *33,* No. 9: 42.
Whitehead, H. R. and Cox, G. A. (1933). Biochem. J., *27,* 951.
Wilson, H. L., Hall, S. A., and Rogers, L. A. (1945). J. Dairy Sci., *28,* 187.

# CHAPTER 9

# STARTER

**Starter** is the common name for a culture of desirable organisms used in the making of cheese, or other dairy products.

**Kinds of starter.** There are many different kinds of starters. The starters that produce acid at a rapid rate are most important for the varieties of cheese described in this text. Other starters are used to produce special effects. In the making of Swiss cheese, organisms are added to assist in the formation of eyes and flavor. Mold is used in the making of some types of cheese to produce desirable flavor, color and consistency. Chromogenic organisms, which form a reddish growth on the surface of smear-ripened cheese, are sometimes used; they cause proteolytic changes that are associated with flavor development.

**Functions of acid-producing starters.** Most starters are used during the making of cheese to produce acid. This acidity development hastens milk coagulation; it assists in the separation of whey from curd; it is chiefly responsible for the plasticity attained by the curd; and it influences the body and flavor of the finished cheese. The acidity affects the growth of bacteria in the cheese during making and ripening. The acidity tends to limit the development of undesirable organisms during the making of the cheese, and it aids in establishing optimum conditions for the actions of desirable organisms and enzymes during ripening.

**Lactic starter.** The most widely used starter for producing acidity in cheese making is commonly known as "lactic starter." It is used in the making of Cheddar, Cottage, Cream, and Bakers' cheese, and many others. It is essentially the same starter that is used in the making of ripened cream butter, cultured buttermilk, and sour cream. The organisms of this starter are required to act at temperatures ranging from 70° F. to 104° F. Lactic starter is quite different from the acid-producing starters that are so important in the making of Swiss and some other varieties of cheese. The latter kinds of starter contain one or more heat loving types of organisms like *Streptococcus thermophilus* and

*Lactobacillus helveticus.* Such organisms remain active in the curd and cheese even though temperatures up to 130° F. are used in the making process.

**Organisms in "lactic starter."** The principal acid-producing organisms in "lactic starter" are *Streptococcus lactis,* or *Streptococcus cremoris*, or both. They convert the lactose of the milk chiefly into lactic acid. Hammer and Baker (1926) called attention to several varieties of *S. lactis: S. lactis* var. *hollandicus*, which produces ropiness especially in young cultures; *S. lactis* var. *anoxyphilus*, which reduces litmus milk comparatively slowly; and *S. lactis* var. *tardus*, which shows relatively slow coagulation of milk. Some of these or other variations of *S. lactis* are found in lactic starters.

Part of the aroma of desirable lactic starter is caused by organisms associated with *S. lactis.* These associated organisms were named by Hammer (1920) *Streptococcus citrovorus* and *Streptococcus paracitrovorus.* These organisms are also known by the names *Leuconostoc citrovorum* and *Leuconostoc dextranicum*, respectively. *S. citrovorus*, he reported, is always present in desirable commercial starters; the organism uses lactic acid and citric acid to produce volatile acidity; it does not produce lactic acid. *S. paracitrovorus*, on the other hand, is not always found in good starters; it ferments citric acid to produce volatile acid; and it produces significant amounts of lactic acid in milk. These associated types make up 1 to 3 per cent of the flora of good starters, according to Hammer.

Hammer and Baker (1923) reported that *S. paracitrovorus* was found commonly wherever *S. lactis* occurred, and that they probably had the same original habitat. *S. paracitrovorus* frequently resisted the heat treatments of pasteurizing. It produced carbon dioxide slowly.

The ability of *S. paracitrovorus* to produce carbon dioxide may have some practical significance in cheese making. This carbon dioxide may affect the texture of Cheddar cheese made from pasteurized milk (Sherwood, 1939; Prouty and Golding, 1946). Some manufacturers of Cottage cheese prefer to use starter which will regularly cause the curd to float. This attribute of such starter is probably caused by a particularly active strain of *S. paracitrovorus.* It is rarely that this gas-forming ability can be detected by the appearance of gas bubbles in the curd of a desirable starter.

Hammer and Sherwood (1923) found that the volatile acids of starters ripened for a long time to a high total acidity were largely acetic plus small amounts of propionic acid. At low total acidities the proportion of propionic acid in the mixture of volatile acids was greater. They found that *S. lactis* produced volatile acids consisting of acetic and considerable amounts of propionic acid; *S. citrovorus* and *S. paracitrovorus* produced volatile acid consisting mostly of acetic.

Michaelian, Farmer and Hammer (1933) found that the starters with satisfactory aroma contained relatively large amounts of acetylmethylcarbinol and diacetyl. Templeton (1937) reported that the volatile acidity of starters could be increased 45% by adding 0.2% citric acid or its equivalent of sodium citrate. This increase in volatile acidity was accomplished with an increase of 10% of total acidity. Prill and Hammer (1939) stated that the factors favoring the production in starters of diacetyl and acetylmethylcarbinol were: addition of citric acid to the milk or ripened culture; aeration or shaking of ripened cultures; holding ripened cultures at reduced temperatures; and development of low pH (high titratable acidity).

Although the organisms associated with *S. lactis* in lactic starter produce a pleasing flavor, they probably play a minor role in imparting flavor to types of cheese like Cheddar. They are probably responsible for much of the characteristic aroma of Cottage and Cream cheese.

Hammer and Babel (1943) published a comprehensive review of the bacteriology of butter cultures; this review is recommended to those who may wish to extend their study of this important topic.

## Requirements for Propagating Lactic Starter

**Technician.** The maintenance of desirable starters in plant practice involves the application of meticulous, bacteriological technique. The starter maker must be carefully trained in the art of his duty. He must be intelligent, skillful, methodical, reliable, and scrupulously clean. He should understand the nature and functions of starters. He must have a keen sense of smell and should enjoy the flavor and aroma of desirable starter.

**Seed starter and cheese starter.** It is essential in maintaining lactic starter to propagate seed starter or "mother" culture, by a routine that keeps it entirely separate from the cheese starter. **Cheese starter,** or **bulk starter,** as it is often called, is the starter that is added to the milk in the cheese vat. **Seed starter** is the small amount of culture that is used for inoculating the comparatively large volumes of milk to make cheese starter.

Seed starter is grown in small, carefully covered containers for maximum protection against contamination. The seed starter is transferred to new containers of sterile milk at 24 hour intervals.

Cheese starter is made in milk cans or starter vats; it is produced by inoculating sterile or practically sterile milk with seed starter. Cheese starter is made only as often as it is needed; this may be daily or at irregular and infrequent intervals under some conditions.

Seed starter and cheese starter are both always used in modern factory practice.

**Source of starters.** The combination of organisms in lactic starter is usually obtained from a commercial laboratory which makes a business of distributing reliable starters. There are several such laboratories in this country and others abroad. They distribute these starters in either liquid or powder form. The essential organisms in these commercial starters may vary somewhat in activity, flavor production, or other minor characteristics. Starters from at least two sources should be carried in cheese factories; which starters are chosen should be determined by the action of the cultures in actual making operations.

**Starter laboratory.** A place must be provided in the cheese factory where the making of starter can proceed with maximum protection from contamination. In a small factory this place may be a clean, sanitary table where seed starters can be transferred in a dust-free atmosphere. Such conditions may be found in the making room at the end of the day's work after the daily clean-up operations have been completed. In larger factories a separate room is usually provided for the handling of seed starter and cheese starter. This room should preferably be isolated from making operations. This suggestion is especially significant for factories that make cheese from pasteurized milk. There are indications that such factories may be especially vulnerable to failure of starter caused by bacteriophage contamination. Whitehead and Hunter (1945) urged the construction of an isolated starter room at a distance from the factory in order to prevent such contamination. Many New Zealand factories have resorted to this practice and have built these rooms on the sides of the factories facing the prevailing winds; they have placed them at distances up to 40 yards from the factories. Others have built their starter rooms in the main factory buildings and have protected them by providing no communication with the making rooms except through outdoor air.

Modern ventilating procedures provide methods of filtering air which enters the starter laboratory. The room can be constructed so that a slight air pressure can be maintained in it. These features minimize the danger of contamination from air which might enter from adjacent rooms.

**Equipment.** The equipment used in maintaining starter may be very elaborate or relatively simple, according to the needs and means of the factory operations. Tables 9:1 and 9:2 summarize minimum and desirable facilities for the making of seed starter and cheese starter. Starter made with minimum facilities can be as good in quality under ordinary conditions as that carried with more elaborate equipment. More elaborate facilities make it possible to propagate starters successfully under difficult conditions.

TABLE 9:1. EQUIPMENT FOR SEED STARTER MAINTENANCE

| FACILITIES | MINIMUM REQUIREMENTS | DESIRABLE FACILITIES |
|---|---|---|
| **Containers** | Glass milk bottles, fruit jars, or prescription bottles | Heat-resistant, small-top containers like Erlenmeyer flasks |
| **Covers for Containers** | Parchment paper hoods and aluminum cups or caps | Parchment paper and glass or aluminum caps |
| **Heating** | Combination steam bath and water bath | Pressure cooker or steam sterilizer |
| **Tempering** | Combination steam bath and water bath | Water bath with automatic temperature control |
| **Measuring inoculation** | Inoculations measured by drops from lip of container | Pipettes made of straight glass tubing, and covered, metal cases for sterilizing and handling pipettes |
| **Incubating** | Combination steam bath and water bath | Incubator with automatic temperature control |
| **Chilling** | Combination steam bath and water bath | Ice-water bath or low temperature refrigerator |

The requirements listed in tables 9:1 and 9:2 need some comments. Glass containers are essential for protection of flavor, which might be impaired by metal containers; they provide visibility necessary to judge the physical appearance of the starter. Milk bottles are recommended when no sterilizer is available: they are rugged, easy to replace, inexpensive, and the small openings can be protected easily from contamination. Fruit jars with glass covers can be used; they are not as rugged as milk bottles, and the larger openings cannot be protected as easily. Prescription bottles in sizes up to eight ounces are very satisfactory. Erlenmeyer flasks made of heat-resistant glass are excellent because they will stand rapid heating and cooling. Prescription bottles will stand sterilizing but must be cooled slowly.

Five-inch squares of parchment paper make good hoods to maintain sterile conditions at the tops of the containers. They can be folded down over the tops of the bottles or flasks and held in place by inverted aluminum cups or glass beakers. These hoods eliminate the necessity of flaming the tops of containers when making transfers. Erlenmeyer flasks may be closed with plugs of cotton by bacteriologists who prefer to use the technique of passing the top of the container through a gas flame to sterilize the lip and top of the container.

The heating of milk for seed starter can be accomplished in a steam bath. A steam sterilizer is preferred because in a comparatively short time the milk can be completely sterilized; this is not possible in a single heat treatment in a steam bath. A pressure cooker, such as is used for home canning, can be applied as effectively, although perhaps not as conveniently as the sterilizer.

The straight glass tubing in 12 inch lengths, that is recommended in table 9:1 for measuring inoculations, is preferred by some technicians. The straight-sided tubing can be effectively cleaned by brushing. In order to protect these simple pipettes it is best to have a metal case in which they can be sterilized and completely protected against contamination until they are ready for use. These pipettes can be sterilized in the steam sterilizer.

TABLE 9:2. EQUIPMENT FOR CHEESE STARTER MAINTENANCE

| FACILITIES | MINIMUM REQUIREMENTS | DESIRABLE FACILITIES |
|---|---|---|
| **Containers** | Well-tinned milk cans | Stainless steel or aluminum cans, seamless construction, for small amounts; and insulated, stainless steel, aluminum, or glass enameled vats with tight covers and sanitary connections, for large amounts |
| **Heating, cooling, incubating** | Self-draining, covered water tank with steam and cold water connections | Insulated water tank or vat with steam, cold water and mechanical refrigeration |
| **Chilling** | Cold water in tank | Refrigeration of tank or vat |

Manufacturers of equipment usually have certain vats which they recommend for making starter in large amounts. These vats must be acid-resistant to withstand the daily contact with starter. They should be easy to clean. There should be no dead-end pockets in gates where a portion of milk might escape the heat treatment. These vats should heat milk rapidly to temperatures approximating 200°F.; they should be properly insulated to maintain high and low temperatures; and they should be built so that cold water or mechanical refrigeration can be used to reduce temperatures quickly to 50°F. or below.

**Selection of milk.** The milk selected for starter affects the flavor and activity of the starter. When the milk is not completely sterilized then the milk may also affect the bacterial content of the starter.

Milk from healthy cows should be selected for starter; mixed milk from a herd is less variable than that obtained from individual animals. Prouty (1940) found that the effects of mastitis infection delayed the growth of *S. lactis* in milk that had been heated for 30 minutes at 144.5°F. to 155°F. Baker and Hammer (1926) observed that milks from different cows gave starters of different quality. The observations of these workers and others indicate the necessity of carefully selecting the source of milk for starter.

The milk selected for starter should be free of off flavors and odors. Such flavors are indicative of carelessness in herd management, or milk production, or perhaps both. These off flavors usually affect the flavor of the starter and detract from its quality.

The milk selected for starter should be fresh in order to obtain minimum bacterial content. Even fresh milk may not have a low bacterial content so that the utmost discretion must be used. The methylene blue test or bacterial counts should be made regularly to determine the bacterial condition of the milk used for starter. Whitehead and Cox (1932) found that organisms of the colon group when grown in milk in large numbers produced chemical entities that were not destroyed by heat and that inhibited the growth of lactic streptococci. They believed that this effect might help to account for the loss of vitality suffered by starters which might be carried day after day in such milk.

Some manufacturers prefer to use skim milk for making starter. There can be no objection to this practice if the milk is of satisfactory flavor, odor, and bacteriological quality. Dry skim milk, if it is of highest quality obtainable, is a very satisfactory medium for starter when it is reconstituted. Horrall and Elliker (1947) found that reconstituted dry skim milk produced more uniform starters of better activity than fresh milk selected at the factory. They preferred to use distilled water for reconstituting the dry skim milk and warned that undesirable tap water might cause starter failure.

**Protecting milk for starter.** When milk for starter has been selected at the factory intake, it should be handled carefully to preserve its quality. Usually it is easy to move the milk in the cans, in which it was delivered, to the sterile milk cans or starter vat, in which it is to be heated. This is a good practice. If it is necessary to move it through pipe lines, these lines should be sterilized to minimize contamination. Milk for seed starter should be placed directly in the bottles or flasks in which it is to be sterilized. Milk for seed starter and cheese starter should be heated to the proper temperatures without delay, cooled after the proper interval, and held cool until the time of inoculation.

**Heating milk for starter.** The minimum heat treatment of milk for starter should practically sterilize it, that is, it should destroy practically all living organisms. Milk for seed starter should be heated to at least 200°F. for 60 minutes. The preferred treatment of milk for seed starter is to sterilize it under steam pressures of 10 to 15 pounds for 15 to 30 minutes. The temperatures attained by these pressures are 240°F. to 250°F. The slightly caramelized flavor and light tan color imparted to the milk by these heat treatments do not impair the quality of the starter.

Milk for cheese starter should be heated to 180°F. to 200°F. for 60 minutes or more. This heat treatment may produce a slightly caramelized flavor and a tinge of tan color. These characteristics, if they are scarcely detectable, may be favorably regarded as indications of adequate heat treatment. If they are excessively pronounced they may be associated with decreased activity of the starter and with defects in the flavor of the manufactured product.

**Cooling milk after heating.** The cooling of the sterilized milk should be done promptly and accurately after the heat treatment. If there is any considerable lapse of time between cooling and inoculation, then the cooling after sterilizing should be to temperatures of 60°F. or less; otherwise the cooling should be to the setting temperature of 72°F.

Temperatures of the milk for cheese starter can be measured with a thermometer sterilized in chlorine solution, if the starter vat itself has no indicating or recording thermometer. Temperatures of the milk for seed starter should never be measured by inserting a thermometer into it. The danger of contamination is not worth the information obtained. To avoid this danger, a glass container, identical to the ones used for the seed starter, can be filled to the usual level with water instead of milk. This water blank can be given the same heating and cooling treatments as the other containers and its comparable temperature can be measured at any time with a thermometer.

**Inoculating.** The inoculation of the sterile milk is a critical step in the making of starter. The work should be done in the starter laboratory, or under comparable sanitary conditions, and at a time when there is a minimum of dust or other particles floating in the air.

The amount of inoculum used depends upon the duration of the incubation period to follow, on the amount of sterilized milk in the container, and upon the growth characteristics of the starter.

The usual incubation period approximates 15 hours in factory practice. Toens and Hammer (1925) found that a 6 to 8 hour incubation period produced a better starter than a 16 to 20 hour period. The shorter period does not usually fit well into the routine of factories which do not operate day and night.

When controlled incubation temperatures cannot be provided, then minor adjustments in amounts of inoculum must be made to compensate for possible variations in temperature.

The amount of inoculum for seed starter can be measured drop by drop. Inoculum for cheese starter can be measured accurately enough, and with minimum contamination, by using the seed starter containers themselves to estimate the amounts. This is better than using other glassware of questionable sterility to obtain more accurate control of volume of inoculum.

Inoculation of starters at the same time each day simplifies the problem of controlling the growth of the organisms so that they will have attained the correct development after the desired period of incubation.

**Incubation temperature.** The control of the temperature of starter is essential during the period when the organisms are increasing in numbers and developing acid. The incubation temperature determines rate of acid development, activity, uniformity, and quality in terms of flavor and other physical characteristics. The incubation temperature for the lactic starter should be 70° to 72°F.

**Chilling starter.** When cheese starter reaches a titratable acidity of 0.70% it should be chilled, excepting when it is to be used immediately. Acidity measurements of these large amounts of starter can be safely made with clean pipettes, unless phage contamination is an important factor in the activity of that particular starter. When there is danger of phage contamination then the pipettes used should be sterile.

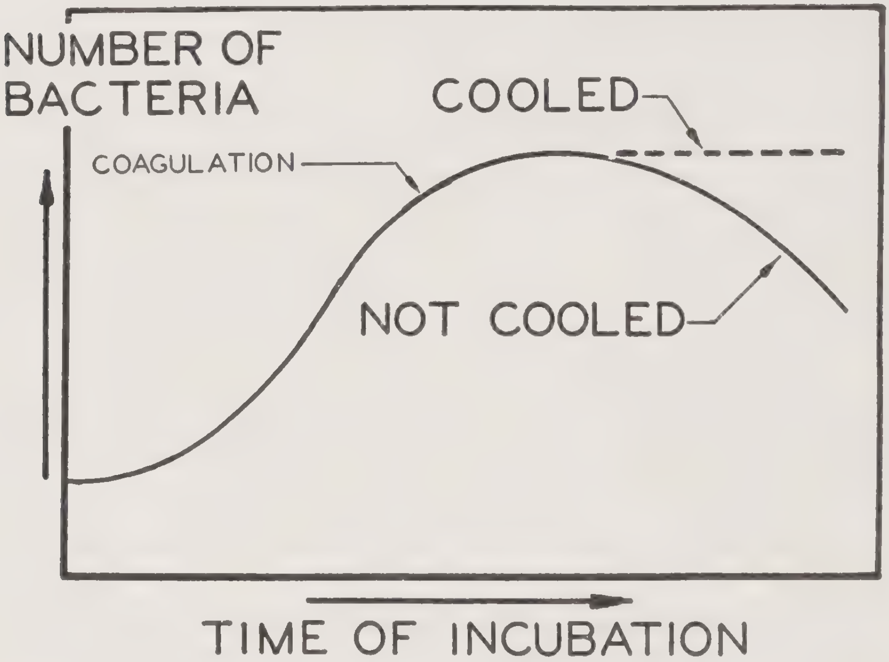


Figure 9:1. Cooling of starter after the proper period of incubation maintains the maximum number of bacteria in an active condition.

Seed starter should be cooled without agitation as soon as it forms a smooth gel. This cooling can be accomplished by placing the bottles or flasks in cold water, or in ice water, or in a refrigerator at 32° to 35°F. It is not necessary to measure the acidity of the seed starter before chilling it. Its acidity can be measured after it has been used for inoculating the sterile milk for the next day's seed starter. If its acidity is too high, or too low, at that time, the next incubation period can be shorter or longer as required, or an adjustment can be made in the amount of inoculum.

The chilling of starters when the proper growth has been attained is essential to maintain maximum activity. Reducing the temperature stops rapid growth of organisms and prevents overdevelopment of acid. The trend of effects of chilling on growth of organisms is diagrammed in figure 9:1. The diagram shows the numbers of organisms increasing slowly soon after inoculation, then faster until the developed acidity coagulates the milk, then more slowly as the medium becomes less favorable for growth. If the starter is not chilled, then the numbers of living organisms begin to decline because conditions in the starter soon become unfavorable. Chilling at the right time suspends the growth activities of the organisms and prolongs their essential vitality without materially injuring their ability to resume active growth under more favorable conditions.

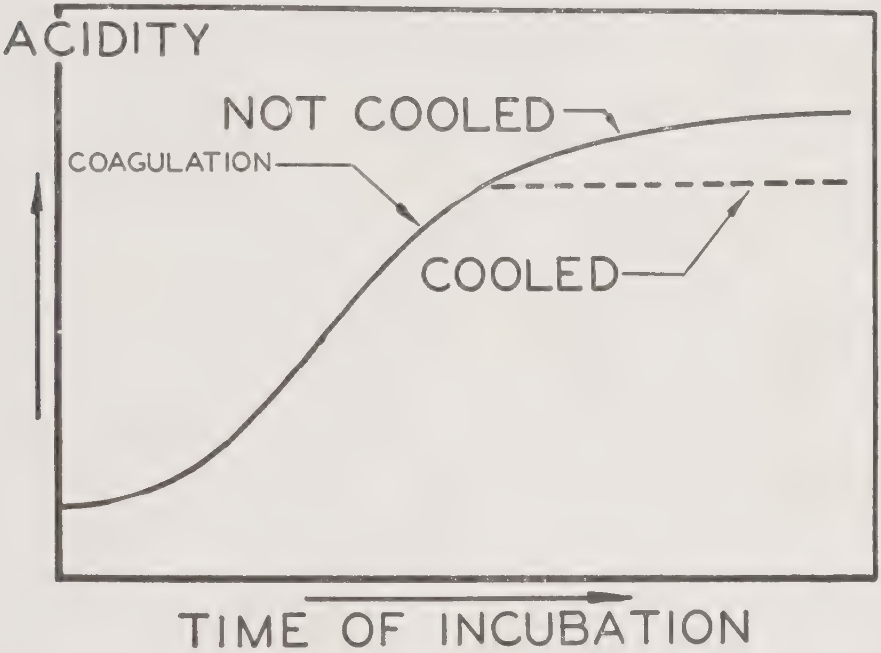


Figure 9:2. Cooling of starter after the proper period of incubation stops acid development and maintains activity of organisms.

In ordinary factory practice it is customary to use the acidity developed in the starter as an indication of its "ripeness" or readiness to use. Figure 9:2 illustrates the general trend of changes in acidity in starter when it is chilled and not chilled. The acidity increases slowly during the early hours of incubation, then more rapidly as the organisms become more active and increase in numbers, and finally slowly as the maximum numbers of living organisms are reached. At this point, or shortly before it is reached, the starter should be chilled. If this is done, the organisms cease growing and the acid development is checked. If it is not done, then the acidity of the starter continues to climb, but more and more slowly, as long as any of the organisms are able to endure the acid and to grow. Comparing figures 9:1 and 9:2 it becomes apparent that excessive acidity development in starter may actually be associated with a smaller number of living organisms. Excessive acid may therefore be an indication of a less active starter. It is so regarded by the more experienced makers.

Chilling of cheese starter when the acidity reaches 0.70% is recommended for maximum activity, if the starter must be held more than an hour before it is used. A temperature reduction of 5°F. will tend to check acidity development. Cooling to 50°F. is desirable if several hours must elapse before the starter is used.

**Over-ripening.** Authorities apparently do not agree concerning the effects on starter action of "over-ripening," such as is caused by holding a starter at incubation temperatures longer than necessary to develop the desired acidity.

Johns and Berard (1943) used three different starters in a study of the effects of over-ripening. They reported that over-ripening failed to slow down either bacterial growth, or acid development, and it did not lower the final acidity attained by the starters. They observed that when a portion of a cheese starter was over-ripened it worked slightly faster during the making operation and produced better flavor than the control portion.

Dahlberg and Ferris (1945) observed that lactic starters inoculated every third day were judged identical in quality and acid development to those that were inoculated daily. But the starter that was inoculated every third day gave slower acid development during making and inferior cheese after ripening.

Lack of agreement concerning the influence of over-ripening on starter action in different factories and laboratories may be caused in part by differences in the starter organisms, differences in management of starters before using them, and differences in methods of cheese making. The real appraisal of starter quality must be based eventually upon its action day after day in the making and curing of the cheese. Since manufacturing operations differ widely from factory to factory, it is probable that minor variations in starter activity might escape attention.

## STEPS IN PROPAGATING LACTIC STARTER

The essential steps in propagating seed starter and using it for making cheese starter are outlined in this section. The procedures described utilize the minimum equipment listed in tables 9:1 and 9:2. The desirable facilities listed in the same tables require no marked change in procedures except when the straight glass tubes are used as pipettes to measure seed starter inoculations. Even when the pipettes are used, the protective technique, which is described in steps 5 through 10, remains the same.

Milk used may be whole milk, skim milk, or dry skim milk providing the bacteriological quality and flavor are satisfactory.

Strains of starters can usually be limited to two or three in the average factory. Each strain is usually carried in duplicate so that the accidental loss of a bottle will not result in the loss of that strain of starter.

When a new starter is received in powder or liquid form from a commercial source or laboratory, it is propagated two or three times according to the instructions of the manufacturer or according to the procedures to be described here. These preliminary propagations are necessary to activate the starter which may be delivered in a dormant condition.

### *Procedure for Making Seed Starter*

For the purposes of this discussion it is assumed that four bottles of seed starter are on hand and are to be carried from day to day with facilities to satisfy "minimum requirements" listed in table 9:1.

(1) Place a half pint of milk in each of four one-pint milk bottles. This will provide adequate inoculation for 200 to 400 pounds of cheese starter.

(2) Cover the bottles by crushing a five-inch square piece of parchment down over each bottle top and capping it with an aluminum cup.

(3) Heat the bottles of milk in the steam bath in flowing steam for 60 to 90 minutes or until the milk develops a slight tinge of tan color. This destroys all but the most heat-resistant cells and the milk is "practically" sterile. A pressure cooker or steam sterilizer, if properly operated, will destroy all cells and produce sterile milk.

(4) Cool the bottles slowly to 70°F. Most breakage of milk bottles in making starter occurs when they are taken from the steam bath and cooled too quickly.

(5) Take one of the bottles of seed starter provided and examine the curd for signs of wheying off or gas formation. Such signs are indicative of defective starter. If it is satisfactory in appearance, shake the bottle until the curd is smooth and creamy. Remove the cup and parchment paper hood together. Place them in an inverted position to use again to cover the starter.

(6) Do not stop at this time to taste or test this open bottle of culture. Take the aluminum cup from a bottle of sterile milk.

(7) With the left hand raise the parchment hood from the bottle of sterile milk and hold it over the bottle top like an umbrella.

(8) Insert the top of the bottle of seed starter under this parchment hood and pour two drops of seed starter into the sterile milk.

(9) Replace the parchment hood and the aluminum cup on the freshly seeded bottle of milk and swirl the milk gently in the bottle to distribute the inoculation.

(10) Replace the parchment hood and metal cup on the seed starter and set it aside to be judged for flavor and tested for acid. Save it for making cheese starter. There should be no delay in performing steps 6 through 10. Open bottles invite contamination.

(11) In a similar manner inoculate the other three bottles of sterile milk using for each bottle of sterile milk a different bottle of seed starter provided. The pattern of this daily inoculation is shown in figure 9:3.

(12) Incubate the bottles of inoculated milk at 70°F. until coagulation occurs. This should be in approximately 15 hours.

(13) Place the bottles of freshly coagulated starter in cold water or ice water until they are needed for the next inoculation.

### *Procedure for Making Cheese Starter*

This procedure described here uses the facilities listed under "minimum requirements" in table 9:2.

(1) Place the necessary amount of milk for cheese starter in milk cans. Do not put more than 75 pounds in a ten gallon can.

(2) Heat the cans of milk with flowing steam in the covered water tank until the temperature of the milk reaches 185°F.

or more and hold it for not less than 30 minutes. Heating at 200° F. for 60 minutes is desirable. Stirring is unnecessary.

A slight tinge of tan color indicates a thorough heat treatment and is not undesirable. If a decided brown color is produced by the heat treatment, it will be accompanied by a pronounced cooked flavor which may be objectionable.

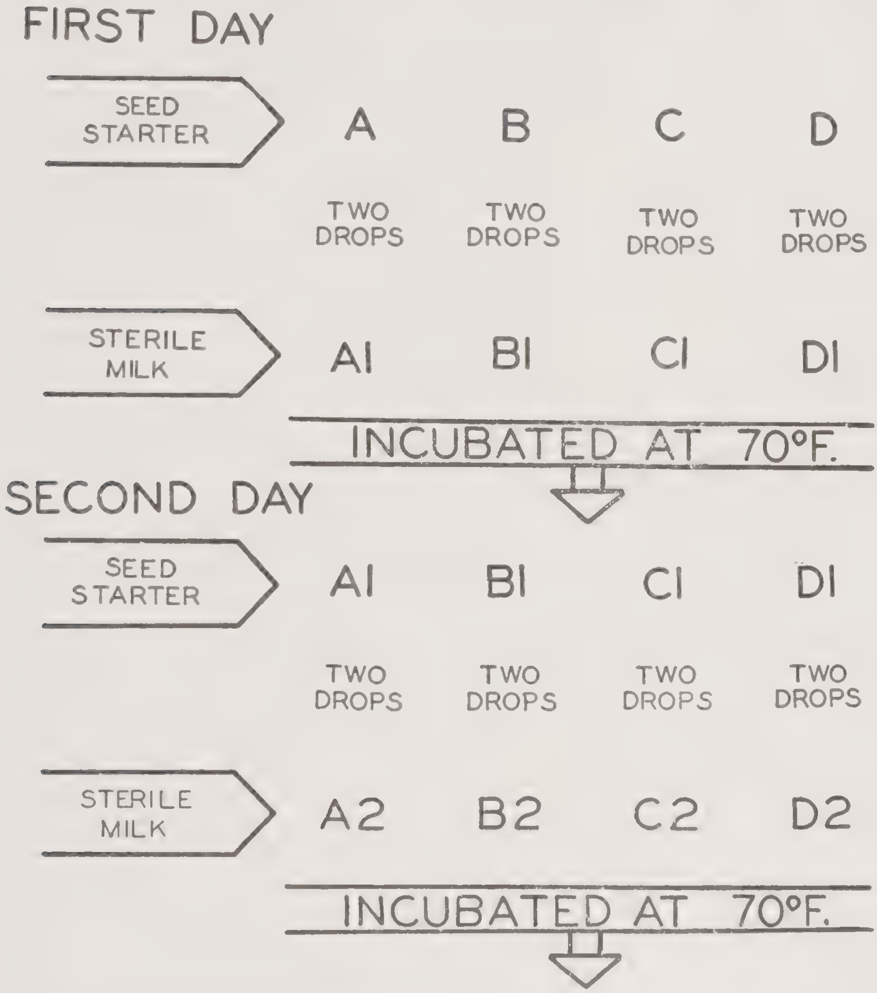

FIRST DAY
SEED STARTER
A
B
C
D
TWO DROPS
TWO DROPS
TWO DROPS
TWO DROPS
STERILE MILK
A1
B1
C1
D1
INCUBATED AT 70°F.
SECOND DAY
SEED STARTER
A1
B1
C1
D1
TWO DROPS
TWO DROPS
TWO DROPS
TWO DROPS
STERILE MILK
A2
B2
C2
D2
INCUBATED AT 70°F.

Figure 9:3. On the first day, each culture, represented by A, B, C, and D, is used to inoculate a half-pint of sterile milk. A is used only to inoculate A1, B is used to inoculate B1, and so on. A1, B1, C1, and D1, after incubation, become the seed starters on the second day. One or more of the four seed starters are chosen each day to inoculate the cheese starter to be used in the vats.

Use a thermometer sterilized in chlorine solution to measure the temperature of the milk.

(3) Cool the milk to 70° F. Keep the cans tightly covered.

Do not use an agitator to equalize the temperature but merely shake the cans by tilting them if necessary.

(4) Select the best of the seed starters remaining after inoculating the sterile milk. The best starter before it is shaken should have a solid curd without gas holes or splits or whey separation. It should show a smooth, creamy consistency after it has been thoroughly shaken. It should have a very slight tinge of tan color. The acidity should approximate 0.70%. The flavor and odor should be pleasingly clean and mildly acid.

(5) Add seed starter to the sterile milk in the cans at the rate of 0.3%. The amount can usually be estimated closely by pouring seed starter directly from the bottles into the cans. Slight variations in the amount of inoculation are not important in making the cheese starter. Cover each can tightly and shake it briskly to distribute the seed starter throughout the milk.

(6) Hold the seeded milk at 70° F. until it thickens and develops a titratable acidity of approximately 0.70%. This should occur under these prescribed conditions in about 15 hours. The starter is then "ripe" and ready to use.

(7) If the ripened starter must be held before using, it should be chilled to 60° F. or below in order to maintain its desirable characteristics.

The activity of starter can be measured by the procedure described in Chapter 28.

## BACTERIOPHAGE AND STARTER

**Bacteriophage** is the name given to a substance or agent that has the ability to disintegrate bacterial cells. The name means "one-that-eats-bacteria." It is commonly known as **phage.**

It was first assumed that this agent was a living substance, perhaps an ultra-microscopic parasite. Northrop (1937) in discussing phage pointed out that, like other viruses, phage can increase in the presence of the host cells.

Like enzymes, phage is inclined to be specific in its action; it may affect only one culture or closely related strains. Nelson, Harriman and Hammer (1939) found that some secondary organisms in starter cultures, which were inhibited but not destroyed, were resistant to the phage. Johns (1941) observed that the mixed strains of organisms in Canadian starters usually prevented complete stoppage of acid development when phage was present. Johns and Katznelson (1941) demonstrated the presence of a polyvalent phage that was able to attack all 10 strains of organisms in mixed starter. Babel (1946a) stated that phage may affect only one culture at first in a factory. Gradually it develops power to attack other cultures or new strains of phage appear that can do so. He found some starters which were more resistant to phage than others. Whitehead and Hunter (1941) indicated that phages are not as specific as early work seemed to indicate. Hunter (1946) found it possible to differentiate between *Streptococcus cremoris* and *Streptococcus lactis* by their sensitivity to phage attack. *S. cremoris* was more resistant to the strains of phage used by Hunter.

There are apparently many types of phage which may attack the organisms of starter. Some of them, but not all, are specific in their action. Some organisms are more resistant than others.

Nelson, Harriman and Hammer (1939) and Hunter (1944) observed that the amount of phage in the culture increases only when the organisms are sensitive to it.

There are many cheese-making areas where phage have caused difficulty in starters used for cheese. New Zealand operators have suffered extensively, perhaps because they have long used pasteurized milk and because they have favored the use of single strain starters. Johns (1943) observed abrupt stoppage of acid development by phage in Canadian factories making cheese from raw milk even when mixed starters containing several strains of acid-forming organisms were used. Factories in the United States, particularly in Illinois and Indiana, have experienced phage attacks. It is entirely possible that instances of "slow" starters in many factories have actually been caused by phage.

Varieties of cheese affected by phage action should include every type that depends upon acid development for the success

TABLE 9:3. EFFECT OF BACTERIOPHAGE ON ACID PRODUCTION IN THE MANUFACTURE OF CHEDDAR CHEESE FROM PASTEURIZED MILK
(Babel, 1946b)

| *Operation* | *Without bacteriophage* | | *With bacteriophage* | |
|---|---|---|---|---|
| | *Time* | *Acidity* | *Time* | *Acidity* |
| | | % | | % |
| Milk | 8:00 | 0.16 | 8:00 | 0.16 |
| Starter added | 8:10 | 0.165 | 8:10 | 0.165 |
| Rennet added | 9:10 | 0.175 | 9:10 | 0.175 |
| Cutting | 9:40 | 0.12 | 9:40 | 0.12 |
| Draining | 11:10 | 0.14 | 11:40 | 0.13 |
| Milling | 1:45 | 0.52 | 4:00 | 0.17 |

of the making operations. The effects have actually been demonstrated in Cheddar many times; Babel (1946b) reported that attacks are also common in Cottage cheese.

The presence of phage in the making of Cheddar cheese can be suspected when acid fails to develop normally after the heating operation. Babel (1946b) made cheese from identical milk with and without bacteriophage. Table 9:3 shows the acid development in these vats. At five hours after draining the acidity of the vat with bacteriophage had scarcely advanced beyond that attained at the time of draining.

When phage was active in the making of Cottage cheese, Babel (1946b) observed only slight acid development during the first 20 hours of setting. During this time the numbers of organisms in the milk increased slightly then decreased to a very low level (7,300 per ml.). The presence of phage could be detected in $10^{-9}$ milliliters of a bacteria-free filtrate. Secondary growth of resistant organisms began after 24 hours and acid production proceeded normally despite the continued presence of the phage in high concentration.

Hunter (1944) pointed out that heavy phage infections stop acid development during the making of Cheddar cheese; light infections may escape detection in the vat; intermediate infections may only cause slow acid development during the late stages of the cheddaring operations. Light and intermediate infections may have little adverse effect on the quality of the cheese according to Hunter.

Whitehead and Hunter (1945) suggested presumptive tests for phage in starter that can be applied in ordinary factory practice. Three drops of starter in 10 milliliters of sterilized skim milk when incubated 24 hours at 72 F. should coagulate the milk. No coagulation is presumptive evidence, not conclusive proof, that phage is present in the starter.

Whitehead and Hunter (1945) observed that complete failure of acid development before the draining of the whey was usually caused by phage in the starter itself. Infection from other sources, such as vat, utensils, air-borne droplets, and milk, produced slow acid development.

Whitehead and Hunter (1945) reported on the use of sprays of hypochlorite solution to disinfect factory rooms. The idea was abandoned as a means of control. They also tested the effectiveness of ultra violet light, given off by "Westinghouse Steri lamp," on air borne phage in a cheese factory and on phage preparations in the laboratory. They found that the light de stroyed the phage when the proper conditions of exposure could be applied, but this exposure was difficult to attain under conditions of constant reinfection.

The control of phage depends on an understanding of the paths of infection. Whitehead and Hunter (1945) and Whitehead (1945) reviewed the essential steps of a practical control program. This program has been evolved principally as the result of years of work by members of the New Zealand Dairy Research Institute at Palmerston North. It is their belief that air-borne phage provides the beginning of trouble. Strict cleanliness in plant operations and sterilizing of all equipment with chlorine solutions tend to reduce the degree of infection. The paths of contamination described by these workers are diagrammed in figure 9:4. They assumed that it is practically

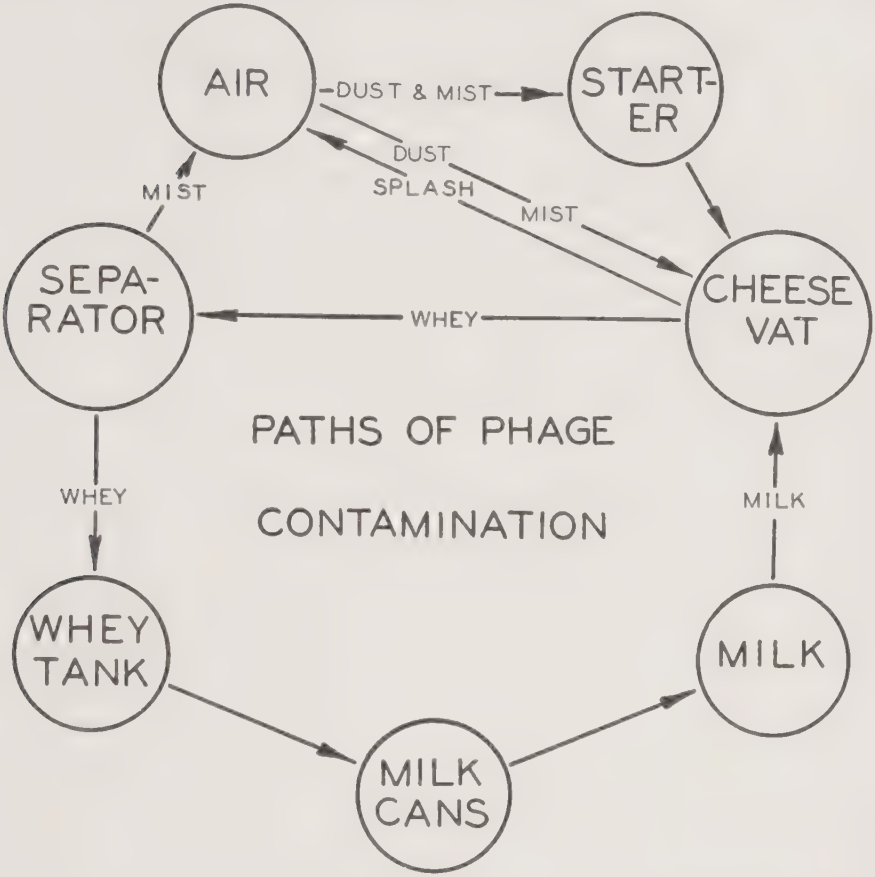

AIR
DUST & MIST
STARTER
DUST
SPLASH
MIST
MIST
SEPARATOR
WHEY
CHEESE VAT
PATHS OF PHAGE CONTAMINATION
WHEY
MILK
WHEY TANK
MILK
MILK CANS

Figure 9:4. Whitehead and Hunter (1945) suggested this graphic illustration to show how phage contamination can gradually build up in factory operations

impossible to operate in such a manner that phage will be completely absent. But under clean conditions the contamination from sources other than starter should not be severe enough to cause stoppage of acid development during the six hour period required for making Cheddar cheese. They therefore recommended that every precaution should be taken to protect the starter itself against air-borne infection.

The New Zealand program to protect starters and cheese against phage effects can be briefly summarized:

(1) An isolated room or building should be provided for starter making. Locate it on the windward side and as far as practical from the factory, whey tanks, sewage disposal system, and roadways where farmers' trucks pass.

(2) Starter vats, cans, and containers should be sealed against air currents by tight fittings and cotton plugs for the small openings through which inoculations are made.

(3) Filtered air forced into the starter building or room should cause an outward flow of air when the door is opened: the flow of this air should remove moisture vapors.

(4) Bulk starters should be made in batches for separate vats so that if one batch is contaminated all vats will not be affected.

(5) At least two "single strain" cultures not sensitive to the same phage should be used. It may be desirable to rotate cultures.

(6) The technicians making and inoculating starter should have clean hands, arms, and clothing. Aseptic, bacteriological technique is essential to prevent contamination during the operations of inoculation.

## References

Babel, F. J. (1946a). J. Dairy Sci., *29*, 496.

Babel, F. J. (1946b). J. Dairy Sci., *29*, 597.

Baker, M. P. and Hammer, B. W. (1926). Iowa Agr. Expt. Sta., Res. Bul. 92.

Dahlberg, A. C. and Ferris, Fred. (1945). J. Dairy Sci., *28*, 771.

Hammer, B. W. (1920). Iowa Agr. Expt. Sta., Res. Bul. 63.

Hammer, B. W. and Babel, F. J. (1943). J. Dairy Sci., *26*, 83.

Hammer, B. W. and Baker, M. P. (1923). Iowa Agr. Expt. Sta., Res. Bul. 81.

Hammer, B. W. and Baker, M. P. (1926). Iowa Agr. Expt. Sta., Res. Bul 99.

Hammer, B. W. and Sherwood, F. F. (1923). Iowa Agr. Expt. Sta., Res. Bul. 80.

Horrall, B. E. and Elliker, P. R. (1947). J. Dairy Sci., *30*, 529.

Hunter, G. J. E. (1944). J. Dairy Res., *13*, 294.

Hunter, J. G. E. (1946). J. of Hygiene, *44*, 264.

Johns, C. K. (1941). Can. Dairy and Ice Cream J. *20*, No. 2:18.

Johns, C. K. (1943). J. of Dairy Res., *13*, 119.

Johns, C. K. and Berard, H. L. (1943). J. Dairy Res., *13*, 127.

Johns, C. K. and Katznelson, H. (1941). Can. J. of Res. *19*, 49.

Michaelian, M. B., Farmer, R. S. and Hammer, B. W., (1933). Iowa Agr. Expt. Sta., Res. Bul. 155.

Nelson, F. E., Harriman, L. A. and Hammer, B. W., (1939). Iowa Agr. Expt. Sta., Res. Bul. 256.

Northrop, John H. (1937). Science *86*, 479.

Prill, E. A. and Hammer, B. W. (1939). J. Dairy Sci., *22*, 67.

Prouty, C. C. (1940). J. Dairy Sci., *23*, 899.

Prouty, C. C. and Golding, N. S. (1946). J. Dairy Sci., *29*, 495.

Sherwood, I. R. (1939). J. Dairy Res., *10*, 326.

Templeton, Hugh L. (1937). Wis. Agr. Expt. Sta., Res. Bul. 133.

Toens, P. and Hammer, B. W. (1925). Iowa Agr. Expt. Sta., Res. Bul. 85.

Whitehead, H. R. (1945). Food Industries, *17*, No. 10:83.

Whitehead, H. R. and Cox, G. A. (1932). J. Dairy Res., *4*, 74.

Whitehead, H. R. and Hunter, G. J. E. (1941). J. Pathology and Bacteriology, *53*, 440.

Whitehead, H. R. and Hunter, G. J. E. (1945). J. Dairy Res., *14*, 80.

## CHAPTER 10

## ESSENTIALS OF CHEESE MAKING

The hundreds of known varieties of cheese all have their common origin in milk. The different varieties are produced by altering certain essential conditions of manufacture.

The manufacture of cheese has two well-defined stages. The first is curd making. It has for its object the production of curd of desired body, texture, acidity, moisture content and form. The second stage is ripening. During ripening microorganisms and enzymes act on the curd under suitable conditions of temperature and humidity to produce eventually the flavors and other physical characteristics which distinguish the finished cheese. In some varieties, the curd-making operations are relatively brief while the ripening operations continue for many months or even years. Other varieties, of which Cottage cheese is a notable example, require no ripening before they are ready to eat.

It seems desirable at this time to introduce the general procedures of making cheese before considering the details of manufacturing some of the common varieties.

The general procedures in cheese making that determine the nature of the finished cheese are:

—control of properties of milk;
—control of curd formation;
—control of changes in the curd;
—control of the removal of whey;
—control of the ripening process.

### Properties of Milk

The properties of milk that are controlled by the maker are chemical composition, biological condition, and physical properties.

**Chemical composition.** The simplest chemical control practiced is the selection of milk of certain animals for the making of special types of cheese. Sheep's milk is used for Roquefort cheese; cow's milk is used for making blue cheese. Cow's milk of low carotene content is sometimes selected for the making of types of cheese which require the lightest possible color to satisfy the customers. When it is impossible to make such a selection, some manufacturers add bleaching agents to the milk to attain the proper color. Such bleaching of the color of cow's milk is common in the making of the blue-mold type cheese.

The most common control of composition practiced is the adjustment of the fat content of the milk. Cheese is made from skimmed milk, partly skimmed milk, whole milk, milk with added dry skim milk, and condensed skim milk, and cream. Such adjustments are partly responsible for the properties of the finished cheese. Cottage cheese, for example, is made from skim milk; Cream cheese, from milk with added cream; Swiss cheese, from milk from which a portion of the fat has been removed; and Cheddar cheese, from whole milk or milk from which only a small percentage of the normal fat is sometimes removed when the milk is rich in fat. These adjustments are partly responsible for the meaty body of Cottage cheese, the smooth consistency of Cream cheese, and they help to make the eyes in Swiss cheese.

The composition of milk is sometimes altered for cheese making by adding certain substances from sources other than milk. Calcium chloride is added to correct faulty coagulation of milk that may be caused by excessive heat treatments during pasteurizing, or by milk from abnormal udders, or by milk that is deficient in calcium salts. The use of calcium chloride in milk for cheese is usually restricted by food laws. If its use is permitted the amount is commonly limited to 0.02% of the weight of the milk. Neutralizing salts have been used to reduce the acidity of milk before pasteurizing; the practice is not permissible under most existing legal definitions of cheese. Saltpeter is sometimes used in European areas to prevent the development of gas in curd and cheese; the practice has probably been followed to some extent in this country despite the fact that it is considered to be an adulteration of the cheese. Dilute organic acids are used in the making of some types of cheese to precipitate at high temperatures the proteins of milk and whey. An example of such a cheese is Ricotta. The acid for this cheese is commonly obtained by the use of soured whey. Dilute acetic acid, however, is preferred by some operators. Pectin has been advocated for making some of the soft, unripened types of cheese. There is no published evidence that it has been applied in this country to any extent.

**Biological conditions.** The biological condition of the milk is partly controlled by modern cheese makers. In the past, makers relied on farm practices to give them milk with the desired bacterial flora. Modern makers now prefer milk with the lowest practical bacterial content so that they themselves can add to it the proper amounts and kinds of organisms. The cultures now commercially available for cheese include: acid-forming starters for the common types of cheese, eye-forming cultures for Swiss, and molds for blue mold cheese and Camembert. There is much interest in the application of special starters for certain effects. It seems probable that special flavor-producing starters may eventually be available for commercial use in Cheddar cheese made from pasteurized milk.

Pasteurization of milk is commonly practiced to control its bacteriological condition. This process has been applied successfully in making Cheddar and most of the other common types. It has been especially successful in making the soft, unripened types of cheese. Its application in making Swiss cheese and cheese of the blue mold type has not been successfully demonstrated on the commercial scale. Pasteurization was originally applied in the making of cheese because it improved the uniformity, quality, and keeping properties of the product. It is being advocated at the present time because, in addition to these very significant benefits, it is also a protection for the public health.

Present knowledge of the enzymes of milk and their relation to cheese ripening is limited. It seems entirely possible that the enzymes of milk play a smaller part in the ripening of cheese than was at one time believed. Milk lipases, for example, if they have any effect at all on cheese, must complete their action during the early stages of the making of the curd (Peterson, et al., 1948). Within a few hours, at most, after the process begins, the acidity of the cheese is beyond the limit where milk lipases can act. This does not exclude the possibility that milk lipases may actually affect the flavor of the finished cheese. Such effects, however, must be achieved before the pH of the cheese is reduced below approximately 6.0.

Enzymes not commonly found in milk can probably accelerate ripening changes in the proteins or fats. The rennet extract used in the making of cheese contains the enzymes rennin and pepsin and perhaps others. Extracts containing enzymes from other animal tissues and from plants have been used in the mak ing and ripening of cheese. It seems probable that this neglected means of controlling the biological condition of the milk may eventually become an important phase of the art of cheese making.

**Physical properties.** Certain physical properties of milk may be altered for better controlling the operations of cheese making.

The normal fat globules can be reduced in size by the use of the homogenizer. This machine divides the fat particles into extremely small globules. The increased surface area of the fat globules and the extent of their dispersion have a profound effect on the curd-forming and moisture-holding properties of the curd. Such a treatment is essential in the making of Cream cheese as it is known commercially today. In the making of certain blue mold types of cheese the homogenizer is used because it accelerates the action of the milk lipase; this process is patented (Lane and Hammer, 1938).

Carbon dioxide, when added to milk, tends to stimulate the action of the enzyme, rennin; the treatment has been used to hasten the coagulation of milk which had been subjected to excessive heat in pasteurizing. Oxygen has been added experimentally to milk to improve the flavor and quality of Swiss cheese.

Heating of milk under vacuum is now used to a limited extent for the removal of volatile odors from milk to be made into cheese. The process pasteurizes the milk at the same time.

Clarification of milk is regarded as essential under commercial conditions for the production of the best quality of Swiss cheese. It has been applied with beneficial results in the treatment of milk for Cheddar and other varieties of cheese. The benefits of the process can probably be attributed both to the removal of substances of greater density than the normal milk and to the mild aeration effect which usually takes place during centrifugal clarification.

## CURD FORMATION

The second major step in the making of cheese is the coagulation of the milk. After the properties of the milk itself have been adjusted, then the characteristics of the curd are further controlled through regulation of the coagulants, the temperature, and the acidity.

**Coagulants.** The coagulants commonly used in cheese making are rennet extract, or the acid developed in the milk by the lactic-acid-producing bacteria, or both. In making a few varieties of cheese the proteins of milk are precipitated at high temperatures by adding small amounts of dilute acid.

Rennet extract is the preparation obtained commercially by extracting with a sodium chloride solution the fourth stomach or "rennet" of young, preferably unweaned, calves. Liquid commercial rennet extracts contain approximately 18% to 20% sodium chloride and a small amount of preservative, usually sodium benzoate. Rennet is also made in the form of powder and paste. Although the commercial preparations are reasonably uniform in coagulating power when shipped from the factory, they will lose strength in storage especially at temperatures above 50°F. They will not endure freezing or exposure to sunlight.

Rennet extract contains two principal enzymes and possible traces of others. These two enzymes are rennin, which is probably responsible for the coagulation of casein, and pepsin, which is believed to be partly responsible for the hydrolysis of the cheese proteins during ripening.

Many different explanations have been offered for the coagulating effect of rennin on the calcium caseinate of milk. Bosworth (1913) reported his belief that the first stage of the effect was probably hydrolytic cleavage and that it should be considered the first step in the proteolysis of casein. Van Slyke and Bosworth (1914) stated that the hydrolytic splitting of casein by rennin caused one molecule of casein to yield two molecules of paracasein.

Precipitation of the casein cleavage product caused by the first stage of rennet action occurs only in the presence of calcium ions. In cheese making, the development of acid by starters increases the calcium ion content of the milk by forming soluble calcium salts from the insoluble calcium phosphates. In this manner the rate of coagulation of milk by the enzymes of rennet extract is partially controlled by the maker.

The sensitivity of the coagulating enzymes of rennet extract to changes in acidity is used in a factory test to determine the "ripeness" of milk. This test has been known as the Marschall Rennet Test, the Monrad Rennet Test, or simply as the Rennet Test. It is actually more sensitive to slight changes in acidity than the titration test, according to Hastings and Evans (1913).

No complete explanation of the coagulation of casein by rennin has as yet been universally accepted by the numerous workers who are interested in this phenomenon. Students who are interested in extending their information in this field of biochemistry might well begin by consulting "Fundamentals of Dairy Science" (1935).

**Coagulation with rennet.** The enzymes of rennet act on normal milk to produce a jelly-like curd which may be made soft or firm according to the desires of the cheese maker. A normal rennet curd is elastic, smooth, homogeneous, and can be sliced with a knife with no appearance of stringiness. At certain stages of its formation the curd can be split with a glass rod, or thermometer, or even with the forefinger when it is inserted at a 45° angle and slowly lifted straight up.

The firmness of the curd formed by rennet action is controlled by regulating the amount of rennet extract, the temperature of coagulation, and the acidity when the rennet is added. Occasionally, calcium chloride is added to increase curd firmness. Larger quantities of rennet, increased temperatures of coagulation, and increased acidity in the milk, may be used to increase the firmness of curd when a typical rennet curd is desired. Amounts of rennet used range from approximately 10 ml. to 12 ounces for 1000 pounds of milk, coagulation temperatures range from about 70° F. to 106° F., and acidity is rarely more than pH 6.3 or 0.10% developed acid, nor less than that of the fresh milk, except in unusual instances when water may be added to the milk in small quantities for special effects. Within these extremes fall most of the routine operations in which rennet is used as the chief coagulant.

**Coagulation with rennet and acid.** Coagulation with rennet alone produces a jelly-like curd that has distinct elastic properties. In the manufacture of the soft, unripened types of cheese the curd has more brittleness. This property is achieved by using minimum amounts of rennet, and high, developed acidity at the time of cutting. Curd formation takes place comparatively slowly over a period of 5 to 10 hours; this is in marked contrast to the formation of a typical rennet curd which commonly occurs in less than 30 minutes.

**Coagulation with acid.** Curd for some types of cheese is formed by the action of acid alone. This acid is normally developed in the milk by the bacteria of lactic starters. This curd is extremely fragile; if it is stirred briskly, it disperses in the form of tiny particles. Such a dispersion is desired in the making of Cream cheese. In the manufacture of Cottage cheese, however, the fragile curd is carefully cut and stirred little, or not at all, until a measure of firmness has been established through loss of moisture. Temperatures ranging from 70° F. to 99° F. are uti lized for this type of coagulation; the lower range of temperature is the one more commonly used.

Coagulation of casein by the development of acidity occurs as the hydrogen ion concentration approaches the isoelectric point of the protein. Complete precipitation of the protein occurs at its isoelectric point. At 72° F., the temperature commonly used for this type of coagulation in cheese making, the isoelectric point approximates 4.7. In terms of titratable acidity, this value approaches 0.55% in the whey which can be centrifuged out of the curd. At higher temperatures, coagulation occurs at lower acidities.

The complete coagulation of casein from skim milk by acid produces the protein in its purest technical form. As the acid develops in the milk, the calcium of the calcium-casein complex is gradually removed until, at the isoelectric point, the casein has an electric charge of zero and it precipitates. The calcium combines with the lactic acid to form the calcium salt of the acid. If more acid is produced, so that the reaction goes beyond the isoelectric point of pH 4.7, then the casein itself combines with the lactic acid to form casein lactate. Casein lactate tends to disperse and the curd becomes more fragile. The yields of acid-coagulated curd tend to decrease when there is an excess of acid developed.

**Coagulation with acid and heat.** This unusual method of curd formation is applied in the making of curd from whole milk and whey. This is essentially an acid coagulation in which the precipitation of the proteins is achieved by using high temperatures and small amounts of dilute acid. The temperature of milk, or whey, or mixture of milk and whey, is raised slowly to a point at which the addition of a small amount of acid can cause rapid and complete precipitation of the proteins. These temperatures range upward from 160° F. to 195 F. depending upon the acidity of the milk and whey.

**Defects in curd formation.** Defects in curd formation are generally of two types. The first is evident in incomplete or delayed coagulation. This may be apparent as lack of firmness in the curd at the proper time, or gelatinous appearance, or milky curd formation. The second type of defect is lack of uniformity of the curd. This may take the form of differences in firmness in different parts of the vat, or stringing of curd on the knives during cutting, or undue sticking of curd to the metal of the vat, or irregular separation of curd from whey before cutting. Some of the common causes of such defects in coagulation are listed under the two types of curd defects below:

*Incomplete or delayed coagulation*

1. Weak rennet extract or use of too little extract
2. Faulty thermometer and low setting temperature
3. Milk over-heated in pasteurizing
4. Milk from inflamed or abnormal udders
5. Colostrum milk
6. Milk of abnormal composition usually associated with seasonal effects
7. Milk adulterated with water, neutralizer, or formalin
8. Delivery of milk in badly rusted milk cans

*Lack of uniformity of curd*

1. Uneven temperature of milk in the vat caused by lack of proper agitation or adding rennet too soon after heating
2. Uneven distribution of rennet extract caused by lack of proper agitation, use of too little water in diluting rennet, or addition of rennet too far ahead of the traveling agitator
3. Agitation of milk after coagulation begins
4. Colostrum milk
5. Scalding of curd knives just before using them.

## CHANGES IN THE CURD

After the curd forms there is an interval of waiting before proceeding with the operations of cutting and handling to separate the curd from the whey. This interval may be only a few minutes or it may be several hours. During this time the curd increases in firmness and in acidity, and decreases in its whey-holding capacity.

**Increase in firmness.** The changes in the firmness of the curd are evident to the sense of touch and in the tendency of the curd to split when cut slowly with a blunt instrument like a glass rod, a thermometer, or even the forefinger. Some operators observe the firming tendency of the curd by laying the back of the hand on the curd close to the side of the vat and then observing the action of the curd when it is pressed gently down and away from the side of the vat. A clean break from the metal is regarded as ideal. Mechanical devices can be used to measure this firmness but, as yet, they have not been made for daily use in the factory. Research workers only have made use of such equipment to reduce to measurable terms, the art and skill exercised by the maker in judging the firmness of the curd required to initiate subsequent steps of the making operations.

**Increase in acidity.** In the making of the types of curd like Cheddar, in which rennet coagulates the milk within a few minutes, increase in acidity is rarely measured before the curd is cut. In such types of cheese the rate of acid development is established before the rennet is added. The brief interval of time elapsing between renneting and cutting permits the development of only small amounts of acid and these developments can be predicted almost as accurately as they can be measured. Firmness of the curd in these types is of more significance than acidity in determining the progress of the making operations.

In the making of types of cheese like Cottage and Cream, there is a long lapse of time between the addition of rennet and starter and the cutting or breaking of the curd. During this interval the nature of the curd is greatly affected by the acidity developed in it. Instead of the firm, elastic, and jelly-like curd formed by the rapid coagulation of milk with rennet, there is formed a soft structure which tends to revert to something like the elastic or rubbery consistency of the typical rennet curd if it is cut before the acidity has attained the correct stage of development. This correct acidity is usually reached when the pH of the curd approximates 4.7; titratable acidity measurements of the whey range from 0.45% to 0.60%. Each variety of cheese differs somewhat in this critical value so that the proper acidity is always stated when the details of manufacture are fully described.

**Decrease in whey-holding capacity.** The object of waiting before cutting the curd is to establish the proper whey- or water-holding capacity of the curd. The action of the rennet continues after the curd has been formed. This is evident in the tendency of the curd eventually to shrink away from the walls of the container in which it is confined. The developing acidity in the curd further activates the enzymes of the rennet extract that affect the condition of the curd. In addition to this indirect effect on the water-holding capacity of the curd, the acidity affects the proteins directly because, as it develops, the reaction moves in the direction of their isoelectric points. In this zone proteins exhibit minimum water-holding capacity.

There are various signs used to detect the proper time to proceed with the cutting or handling of the curd. Firmness is usually measured by sense of touch; acidity limits may be detected by sense of smell, taste, titration, or electrometric or colorimetric measurements of pH; and water-holding capacity may be indicated by drops of whey that appear like beads of sweat on the surface of the curd. These beads of "sweat" may gather to form a thin layer of whey on the surface of the curd. Sweating of curd is commonly observed in the making of Cottage, Bakers', and Camembert cheese. It is not a normal characteristic of the curd at cutting in making Cheddar or Brick cheese. In these last two varieties, and in many like them, the firmness of curd determines the time of cutting.

## REMOVAL OF WHEY

The removal of whey from curd changes the soft, jelly-like curd into the relatively firm form of the finished product. Control of this process is one of the chief arts of the maker because it establishes, to a great extent, the final composition and quality of the cheese. If too much whey is retained in the curd, then the cheese will be sour, because the whey contains in solution, lactose, the mother substance of lactic acid. If the whey is removed too slowly, or too rapidly, then other defects appear in the curd and eventually in the cheese.

The control of the removal of whey begins with the procedures establishing the properties of the milk. It continues through the procedures of controlling curd formation and changes in the curd. All three procedures establish the trend and activity of the forces acting within the curd to expel the moisture. These forces are three in number: action of rennet; action of acid; and action of heat. The subsequent making operations aid these natural forces by three mechanical manipulations: cutting the curd; heating the curd; and, finally, separating the whey from the curd.

**Cutting the curd.** Cutting the curd increases the total area of the surfaces from which the whey can escape; it also makes possible a uniform heating of the entire curd mass. The particles of curd after cutting are usually made as uniform in shape and size as possible in order to achieve these objectives.

The size of particles after cutting influences the rate of firming, the ease of handling the curd, and in some varieties, the texture or openness of the cheese. Smaller particles of curd lose moisture faster than larger ones. If they are not uniform in size, the differences in moisture content of the larger and smaller particles affect unfavorably the characteristics of the finished cheese. The size of particles affects ease of handling because when particles are too large they are more easily broken into pieces of irregular shape and size. The size of particles may affect texture of cheese because, in shaping cheese into its characteristic final form, these particles must be settled together. Small particles fit together closely and the openings in the cheese tend to be smaller; larger particles form fewer and larger openings. This is well illustrated when Stirred-curd and Colby cheese are made by cutting the curd into one-half inch or one-quarter inch cubes. It must not be assumed, however, that size of particles is the only factor which affects the size of the openings in cheese.

**Heating the curd.** Heating curd accelerates the loss of moisture. This effect is produced because heat stimulates rennet action and directly affects the physical ability of the curd to hold moisture. Small changes in temperature are very effective. For this reason it is advisable to heat curd slowly so that the heat will penetrate through it before the outer layers have been reduced to a relatively impermeable film. When this happens, the curd particles must be stirred vigorously to break this film and release the excess moisture. This is wasteful of both cheese solids and energy.

The operation of heating is called "cooking" or "scalding." These terms are not justified in the usual meaning of these terms. The highest "cooking" temperatures used rarely exceed 130 F. One of the exceptions happens to be Cottage cheese in the manufacture of which temperatures as high as 150 F. are sometimes mentioned—but seldom used. The majority of varieties of cheese require an increase in temperature of only a few degrees; some are made with no heating at all after cutting.

Heating has another important effect because it is related to the activity of the organisms in the cheese. In making those varieties that require the action of *Streptococcus lactis*, the maximum heating temperatures are not long, if ever, above 104 F. In other types of cheese, like Swiss, the heating is high enough to exclude the action of some undesirable organisms and to encourage the development of the heat-loving types necessary for proper ripening.

Types of curd in which rennet is the chief coagulant tend to stick together after cutting and during heating. This effect is particularly apparent if heating is too rapid and if agitation is inadequate in force, frequency or continuity. This lumping together of the curd defeats the purposes of cutting; it is undesirable and unnecessary. The remedy is to heat more slowly and to stir the curd vigorously enough to keep the particles apart but not hard enough to break them.

**Separating curd from whey.** The separation of curd from whey is a rapid operation in the making of some varieties of cheese while in others it may require several hours. If heat is applied to curd after cutting then the whey is allowed to remain with the curd at least until the heating operation ends. Cheddar cheese furnishes an example of this treatment. When the curd is not heated after cutting or breaking then the drainage of whey frequently begins immediately. Bakers' cheese is an example of this method of curd handling.

The mechanical manipulations of separating curd from whey are highly variable in practice. There are at least four methods that are commonly used. (1) The curd may be placed on cloths which retain the curd but allow the whey to flow through; Cream cheese is drained in this manner. (2) Another practice is to dip or pour the soft or partially firmed curd and a portion of free whey into perforated forms or hoops. These hoops may have no bottoms so that the curd rests on matting, or coarsely woven cloth, or metal draining surfaces. The whey escapes through the hoops and through the surface on which they stand. Brick cheese is drained in this manner. (3) A third method uses a cloth to gather the curd together into one mass beneath the surface of the whey. The edges of the cloth are lifted up and out of the whey and gathered together above the curd thus forming a bag. In this bag the curd is lifted out of the kettle or vat. This is the procedure used in dipping Swiss cheese. (4) A final method permits the particles of curd to settle to the bottom and sides of the vat beneath the whey. Then the supernatant whey is removed through a valve in the end of the vat, or through a siphon. Cheddar cheese curd is separated from the whey by this method.

The separating of curd from whey marks a definite stage in making that is usually called **dipping, draining, running,** or **drawing.** This operation does not complete the removal of the whey. Curd may continue to lose whey for many hours, as in making Cream cheese. It usually continues in the heated types of curd, like Cheddar and Brick, until the temperature of the curd approaches 70° F. and until the acidity development in the curd nears its maximum or becomes relatively slow to change. During this interval the curd may be protected from rapid cool ing to encourage the action of the acid-producing organisms in it.

The last stage in removing the whey from the curd is the operation of pressing. This operation is frequently used to mold some varieties of cheese into final shape for ripening. The pressure applied varies with the size of the loaves of cheese; large styles, like Cheddar, require more pressure than small styles, like Brick cheese. The form of hoop in which the cheese is pressed, the nature of the curd itself, and the type of surface needed to begin the ripening operation, all help to determine the amount and duration of pressing. Such matters must be considered in detailed descriptions of making operations.

Some varieties of cheese begin curing with a smooth, sound surface or rind. Curd for such cheese is kept warm enough during pressing to permit the curd particles on the surface of the cheese to fuse together. Examples of such cheese are Swiss and Cheddar. Other varieties, like Cream and Bakers' cheese, have no rind. These varieties may be iced during the draining and pressing operations to check further development of acid and to prevent the growth of undesirable organisms.

The process of separating curd from whey is stimulated in some varieties of cheese by the addition of salt. Salting has a profound influence on all physical properties of the curd. It has much to do with subsequent biological changes during ripening. In a few kinds of cheese the salt is sprinkled over the finely divided curd before the curd is pressed into the desired shape and size. This is done in making Cheddar. In other types of cheese the curd is shaped first and then salted by placing the cheese in a salt brine or by sprinkling or rubbing salt on the surface of the cheese. Salting is the last step in curd making when the cheese is salted before pressing; it is the first step in ripening if it is added after the cheese has been shaped.

## Ripening

Some cheese is ready to eat as soon as curd making is ended; other kinds are cured or ripened in a few days or weeks; some may take months, or even a year or more, to develop proper qualities.

The ripening of cheese has for its object the development of specific physical characteristics of flavor, odor, body, texture, and color. The ripening changes are accompanied by decomposition of proteins, hydrolysis of fats, production of volatile fatty acids, fermentation of lactose and organic salts, evaporation of moisture, changes in acidity, changes in oxidation-reduction potential, and production of gas. Some of these changes are clearly apparent in the physical characteristics that have been mentioned. Others of these changes can be detected only by careful analytical procedures. The relation between the changes in cheese that can be measured by analytical procedures and the development of desired properties of the fully cured product has not been fully established.

The biological agents responsible for the continuing changes in ripening cheese are bacteria, yeasts, molds, or enzymes, or combinations of them. Not all of these function in the ripening of all kinds of cheese. They may not bring about the same changes in different kinds of cheese even if all of them are present. Within certain limits, their environment controls the activity of these ripening agents.

The art of ripening cheese is based upon control of its environment. The environment, however, cannot be fully effective without the preparatory controls established during curd making. The general procedures for making the curd, from the time the milk was selected until the curd was finally molded into its finished shape, were all planned to encourage specific ripening changes in the proper environment. These general procedures placed, or developed, certain microorganisms in the curd; they determined its chemical properties, such as moisture, acidity, and salt content; they regulated the shape, size, texture, and consistency of the uncured cheese. These are some of the chief properties of the fresh cheese that condition it for the desired ripening changes; they are as characteristic of the uncured cheese as are the distinctive flavors, and other qualities of the fully ripened product. But the ideal characteristics develop only under optimum conditions. Deviations from the optimum environment tend to produce abnormal characteristics in flavor, body, texture, or appearance, or in rate of curing. This specificity of curing environment for each type of cheese merely reflects the selective action of environment upon the biological agents which activate the changes in cheese ripening.

Examples of association of kinds of cheese with ripening environment can be mentioned here. Mold ripened types generally require a cool, wet environment; Camembert, Roquefort, Gorgonzola, and Blue cheese are notable examples. Types of cheese ripened with a characteristic growth of yeasts and bacteria on the surface do best in a moderately cool, wet room; examples of such types are Brick, Münster, Limburger, and Tilsit. Cheddar requires a cool or cold temperature and endures low humidity because it is usually protected against excessive evaporation losses by a coating of wax, or paraffin, or by a thick rind. Swiss receives its characteristic eye formation in a warm, wet room and its final curing under conditions suitable for Cheddar.

The rate at which ripening progresses depends on the properties of the freshly made curd as well as upon the environment established for the ripening process. In general, low moisture content, high acidity, high salt content in the cheese and low temperatures and low humidity in the curing rooms are associated with long curing periods. Long storage of all types of cheese essentially attempts to inactivate partially the biological agents in the cheese. This is best accomplished by storing the cheese at temperatures approximating, but not below, the freezing point of the cheese. A temperature of 35° F. is well above freezing temperatures and is usually regarded as satisfactory for general storage conditions.

## References

Bosworth, A. W. (1913). J. Biol. Chem., *15*, 230.

"Fundamentals of Dairy Science" (1935). Associates of Lore Alford Rogers. New York, N. Y. Chemical Catalog Co. 1935.

Hastings, E. G. and Evans, Alice C. (1913). U. S. Dept. of Agr., Bur. An. Ind., Circ. 210.

Lane, C. B. and Hammer, B. W. (1938). J. Dairy Sci., *21*, 161.

Peterson, Merlin H., Johnson, M. J., and Price, W. V. (1948). J. Dairy Sci. *31*, 39.

Van Slyke, L. L. and Bosworth, A. W., (1914). N. Y. (Geneva) Agr. Expt. Sta., Bul. 31.

# CHAPTER 11

# CHEDDAR CHEESE MAKING: PRELIMINARY STEPS

The making of Cheddar cheese will be discussed in this and the following two chapters. The information presented will follow the making sequence of handling milk, curd and cheese. The discussions will be concerned with normal methods of manufacture such as one would encounter in using milk of good quality. Consideration of abnormal conditions will be reserved for separate treatment in Chapters 15, 16, and 17.

## KEEPING RECORDS

Few manufacturing processes require more careful, skillful mechanical manipulation than does cheese making. A successful cheese maker must be quick to think and to act. He must know the details of his process and the principles underlying the operations in order to control variations caused by climatic, biological and chemical conditions. Careful records of manufacturing operations and the results of them are essential for intelligent action. Figure 11:1 is an example of a form for recording information in a systematic manner. These records should be kept and consulted until the cheese is cured and sold. The accumulated records provide a wealth of information on seasonal trends as well as upon the success and efficiency of manufacturing operations.

## STERILIZING EQUIPMENT

Milk should be received and processed only in clean and practically sterile utensils. This means that the weighing can, pipelines, pumps, filters, pasteurizer, vats, rakes, agitators, knives, thermometers, pails and any other equipment or utensils that come in contact with the milk should be sterilized just *before* they are used. This can be accomplished by rinsing or immersing the equipment and utensils in a sterilizing solution like 100 parts per million of chlorine. Liberal amounts of hot (180 F.)

## MANUFACTURING RECORD

Lot Number ........... Vat Number ........... Date ...........

Pounds of milk ....................

Pounds of starter ..................

Total in vat ..................

| Per cent of | Milk | Whey |
|---|---|---|
| Fat ..... | | |
| Total solids.. | | |

| Pounds of | Milk | Whey |
|---|---|---|
| Fat ...... | | |
| Total solids | | |

Quality of Milk

Appearance ......................

Odor ............................

Taste ...........................

Methylene blue ....................

Lactometer Reading ................

Quality of Starter

Per cent of Starter ............

| Observations on | | Operation | Time | Temperature | Acidity | Rennet Test | Comments |
|---|---|---|---|---|---|---|---|
| Observations on | Milk | Receiving ..... | | | | | |
| | | Adding Starter | | | | | |
| | | Renneting ..... | | | | | |
| | Curd and Whey | Coagulation ... | | | | Hot Iron | Curd Condition |
| | | Cutting ....... | | | | | |
| | | Steam on ..... | | | | | |
| | | Steam off ..... | | | | | |
| | | Dipping ....... | | | | | |
| | | Packing ....... | | | | | |
| | | Milling ........ | | | | | |
| | | Salting ....... | | | | | |
| | | Pressing ....... | | | | | |
| | | Dressing ...... | | | | | |

| Weight of Cheese | Pounds | Yield of Green Cheese | Pounds |
|---|---|---|---|
| After pressing ............ | | Per 100 pounds of milk..... | |
| After paraffining .......... | | Per 1 pound of fat ........ | |
| At boxing ................ | | Per 1 pound of total solids | |

Number of Cheese ...........

Style of Cheese .............

Pounds of milk per 1 pound of cheese ..................

Grade of cheese ...................

Figure 11:1. The manufacturing record is an essential part of the quality improvement program of every factory. It is a record of the efficiency of the manufacturing operations.

water are very effective if the contact is maintained for two or more minutes. Blowing steam from a hose over open equipment does not kill bacteria.

## RECEIVING THE MILK

The inspection of milk at the intake of the cheese factory is one of the most important operations. The man in charge of the intake work must know that any milk of unsatisfactory quality which is not rejected detracts from the quality of the cheese. He has the further responsibility of rejecting milk that is illegal in composition or extraneous matter content. The Milk Quality Code of the National Cheese Institute shown on page 95 indicates clearly the responsibilities of the operator who receives milk.

When cheese is made from pasteurized milk, the same rigid inspection of the incoming raw milk must still be applied. The quality of pasteurized-milk cheese depends on the quality of the raw milk. No milk that is unacceptable for raw-milk cheese should be used in pasteurized-milk cheese. Defects in flavor, odor, cleanliness, or bacteriological condition that can be detected in the incoming milk will usually be apparent in some degree in the cheese made from that milk after pasteurization.

Inspection of milk at the weighing stand furnishes information to guide the maker in the treatment of the milk and curd: it enables him to predict the general level of quality of the finished cheese.

After the milk has been examined for quality and accepted, it is weighed, and a representative sample is taken of each patron's milk for analysis. The milk is then run into the receiving vat.

## FILTRATION

It is conceded that milk received by the factory should be free of extraneous matter. Filtration or clarification of milk, however, is commonly practiced as an added precaution to safeguard the finished product.

Filtration of milk at the cheese factory does not justify the acceptance of insanitary milk. Miersch and Price (1943) found that the capacity of a given filter varies with the condition of milk, such as its cleanliness, viscosity, acidity, fat, and curd content. Preheating of milk is sometimes used to increase filter capacity. Efficiency of a given filter is affected by the type of pad used, the re-use of washed pads, and the volume and sanitary condition of the milk. Factory operators who try to wash and use filter pads over again take an unjustified risk. Such pads are apt to contaminate the milk. Furthermore, the first flow of milk through the pad develops channels in the fabric and decreases the filtering efficiency.

There is no available information to show conclusively that filtration of milk improves the quality of the finished cheese.

## CLARIFICATION

Clarification of milk by the centrifugal method has been used commercially for many years in making Swiss cheese. It has been advocated for many years for Cheddar cheese but has been used in relatively few factories.

Babcock (1895) reported that clarification of milk in winter repressed gas, but it did not do so in summer. He used an ordinary De Laval separator for clarification. He stated that the quality of the Cheddar cheese made at all seasons was improved by the process.

Fisk and Price (1923), Combs, Martin and Hugglar (1924), and Wilster (1930) all observed that clarification of milk caused improvement of flavor and general quality of Cheddar cheese. Hood and Hlynka (1946) confirmed these results in commercial practice in a large Canadian factory. They observed no adverse effects of the process.

Clarification, like filtration, does not justify the acceptance of insanitary or inferior milk. Operators who are attempting to produce cheese of highest quality can use this process advantageously.

## PASTEURIZATION

Several states have laws which require the pasteurization of milk for Cheddar cheese or some treatment of the cheese to make certain that pathogenic organisms from the milk supply cannot reach the consumer in the cheese. It seems probable that eventually all Cheddar cheese shipped in interstate commerce will have to satisfy similar standards. The definitions of pasteurization that appear in United States Public Health Service (1939) Public Health Bulletin 220, are quite generally regarded as satisfactory standards. The phosphatase test of milk, or cheese, or both, is generally accepted as a measure of the effectiveness of the heat treatment.

High-temperature, short-time pasteurizing at 160 F. for 15 to 20 seconds is most commonly used for Cheddar cheese. Regenerative systems are essential for efficient operation. These machines, if operated at the proper temperature and for the right holding interval, will produce milk that is negative to the phosphatase test without materially affecting normal coagulation of the milk with rennet.

The holder method of pasteurization, requiring heating to 143° F. for 30 minutes as minimum treatment, is frequently used in plants where cream pasteurizers of the batch type are available. This treatment uses more water for cooling and more steam for heating, unless a regenerative system to operate with the batch method is used. Such installations have not appeared as yet in factory practice.

The adoption of pasteurization of milk in factory practice has sometimes been opposed on the grounds that it encourages the use of inferior milk. The accusation was well founded in too many factories in the pioneer stages of development of pasteurized-milk cheese. Pasteurization destroyed the undesirable organisms which otherwise could not be controlled; this fact led to the acceptance of milk of submarginal quality by some factory operators. Such practices today are not condoned by alert food regulatory officials and leaders in the cheese industry.

It is true that the improvement in the quality of cheese obtained by pasteurizing is greatest when the quality of the raw milk is inferior; it is also true that the quality of pasteurized-milk cheese is improved by using a better supply of raw milk; Price (1927) pointed out these facts. Defects in raw milk are transmitted to the cheese even though the milk is pasteurized. Wilson, Hall, and Rogers (1945) studied the effect of pasteurizing milk of poor bacteriological quality by inoculating raw milk with *Aerobacter aerogenes*, or *Streptococcus lactis*, or both. This milk was held under suitable conditions to produce in it the characteristics of an inferior milk supply; then it was pasteurized and made into cheese. The cheese made from this milk was compared with cheese made from identical milk that had not been injured by the inoculation and holding treatment before pasteurizing. The cheese made from the inoculated milk was considerably inferior to the control. They concluded that pasteurization was only partially effective in correcting the faults of an inferior milk supply.

Pasteurized milk, when made into Cheddar cheese, produces a more uniform cheese of better quality and superior keeping properties. The cheese made from pasteurized milk develops flavor more slowly than that made from raw milk. The curdy characteristics of the fresh cheese made from pasteurized milk, however, disappear in the course of ripening at practically the same rate as those of raw-milk cheese.

The successful manufacture of Cheddar cheese from pasteurized milk is only possible when a lactic starter of high quality is used. The acid developed during the curd-making operations is determined by the management of the starter and the activity of the organisms in it. There is considerable interest in the possible application of special starters for increasing the rate of flavor development in Cheddar cheese. Such starters are not available now for commercial use; some have been applied on the experimental scale.

One of the chief advantages of using pasteurized milk in the making of Cheddar cheese is the regularity of the procedure. A schedule of a recommended process is given in Chapter 14 and an outline of time and acid development during making is shown in table 14:1 (Price, 1944).

## RIPENING THE MILK

The formation of acid in milk from the time it is received until the rennet is added is commonly known as **ripening.** Ripening in raw milk is caused by the normal flora of the milk and by the addition of starter; the starter alone accomplishes this purpose in pasteurized milk. Ripening aids in the formation of desirable curd, in establishing a favorable bacterial flora, and in controlling moisture. The ripening period may last for an hour or more, and under other circumstances, it may be practically omitted.

Ripening milk establishes the rate at which acid develops. Measuring the rate at which acid develops in the milk can be accomplished best by making tests for acidity during the ripening period. Tests made half an hour before adding rennet and again just before the rennet is added show how much acid, or ripeness, develops in that length of time.

**Measuring ripeness of milk.** Ripeness of milk is usually measured in factory practice by titration for acidity, or by the rennet test. These tests are described in Chapter 28. Electrometric measurement of hydrogen ion concentration, or pH, can be used, although at present it is more commonly applied in control laboratories than in cheese factories.

The proper ripeness of milk for Cheddar cheese is usually attained when the titratable acidity developing in the milk amounts to 0.01 or 0.02 per cent in the 15 minute period preceding the addition of the rennet. Some makers rely upon the development of a certain percentage of acidity rather than upon the rate of acid development. These makers assume that the acid development in the ripening period is indicated by the single test made just before the rennet is added. This assumption is only justified when it is applied to the same milk in the same factory, day after day. Makers in different factories who use the single test to measure ripeness do not always agree on the proper titratable acid at the time of setting. This is explained by the fact that the acidity of mixed milk from many herds can be expected to vary from 0.145 to 0.165 per cent (Sommer, 1935). This does not preclude the possibility of higher titration values in mixed milk at factories which receive a predominance of Jersey and Guernsey milk, or other milk of especially high total solids content. Sommer and Hart (1919) reported acidities of individual samples of fresh milk ranging from 0.102 to 0.257 per cent. Such extremes for the whole milk supply of a factory would be unusual but entirely possible under certain circumstances. Under such conditions the application of the titration test for ripeness should certainly be based upon a rate of acid development rather than upon any specific percentage of acid that has not been determined by the characteristics of that particular milk supply.

TABLE 11:1. ACIDITY SCHEDULE FOR CHEDDAR CHEESE

| *Operation* | *Time elapsed* | *Changes in acidity* | | |
|---|---|---|---|---|
| | Hours: minutes | % | pH | rennet test |
| Adding starter | 0:0 | 0.0* | 0.0* | 0 space* |
| Adding rennet | 0:45 | 0.01* | 0.05* | ½ space* |
| Coagulation | — — — | — — — | — — — | — — — |
| Cutting | 1:15 | 0.0** | 0.07*** | hot iron test |
| Dipping | 3:00 | 0.02** | 0.45*** | 1/16 inches |
| Packing | 3:15 | 0.07** | 0.50*** | 1/16 inches |
| Milling | 5:15 | 0.30** | 1.15*** | ½ inches |
| Paraffining | 96:00 | — | 1.40*** | — |

* Acidity measurements made on milk; the acidity of milk with added starter is designated 0.0.

** Acidity measurements made on whey; the acidity of whey at cutting is designated 0.0.

*** Acidity measurements made on curd; the acidity of milk with added starter is designated 0.0.

The rennet test is particularly sensitive to changes in acidity (Hastings and Evans, 1913). In making this test, the procedures and precautions given on page 498 should be observed. The proper ripeness of milk for Cheddar cheese is usually established when the change in the Marschall Rennet Test approximates one-half space in 45 minutes. Like the titration test for measuring ripeness, the rennet test can be an indication of ripeness attained by making a single test just before adding the rennet. It is not possible to indicate a specific test value which can be arbitrarily applied to all milk supplies. Two spaces on the Marschall cup in one factory might be equivalent to four spaces at the time of setting in another factory, or even in the same factory at another season of the year. The proper degree of ripeness must be judged by the conformance of the making operations to the schedule suggested in table 11:1.

The proper ripeness of milk in terms of changes in pH is usually attained in Cheddar cheese when there is a change of 0.05 pH units in the period of 45 minutes preceding the addition of rennet.

### ADDITION OF STARTER

The addition of starter to the milk is the first step in controlling the acid development in curd making. The acidity of the finished cheese is determined to a great extent by the success of this operation. Proper control of acidity is indicated by the acid developed at each of the important stages of the making operations in table 11:1. Amount of acid developed, time required for its development, and condition of the curd at each stage or time in the making process are the three factors by which the operator can judge the success of his starter manipulations.

**Time of adding starter.** Starter is usually added to the vat before all of the milk has been received or before it has all been pasteurized. If the milk is cold when the starter is added, then little or no ripening occurs until the milk reaches temperatures approximating 75° to 80° F. Irregularities in temperatures of holding the milk and duration of holding make control of acid development in the making process unusually difficult. The activity of the starter, the amount of starter used, and the quality of the milk influence the time when starter is added. It is good practice to keep these factors as uniform as possible when a successful factory routine has once been properly established.

**Starter and acid control.** The two factors which can be most easily varied to control the acid development are the amount of starter added, and the time interval between adding starter and adding rennet. The amount of starter required depends on the quality and acidity of the milk, on the time interval between adding starter and rennet, and on the activity of the starter. If acid develops too fast according to the schedule of table 11:1, reduce the amount of starter, or reduce the time interval between adding starter and rennet, or keep the milk in the vat cold to prevent growth of starter organisms, or do all of these things if the acid is much too fast. If acid development is too slow, then follow the opposite of these suggestions. This problem is discussed in Chapter 15 in connection with acidity defects in Cheddar cheese.

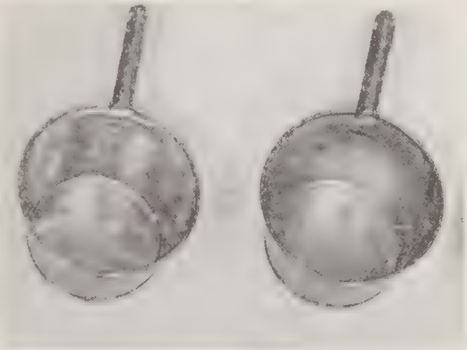


Figure 11:2. The dipper at the left has a solid bottom; the one at the right has a strainer bottom. (*Courtesy of Damrow Brothers Company*).

**Amount of starter.** Normal milk of good quality needs from 5 pounds to 10 pounds of active starter for each 1000 pounds of milk if the starter is added 60 to 30 minutes before the rennet. This treatment assumes that the temperature of the milk approximates 85°F. This treatment should produce the acid development in the making process shown in table 11:1. Smaller amounts of starter can be used when the milk is of excellent quality, when the milk is raw and developing acid before starter is added, when the time between the addition of starter and of rennet is prolonged, and when the starter is especially active. It is better practice, as a general rule, to add too little starter and to ripen the milk a little longer if necessary.

**Adding starter to milk.** The starter for Cheddar cheese is in a coagulated condition when it is ready to use. It is thoroughly stirred until it is smooth and creamy in consistency. It is then strained to remove any small lumps or hardened particles that might cause white spots in the cheese. After the necessary amount of starter has been measured out, it is added to the milk in the vat and stirred vigorously in such a way as to accomplish thorough and uniform distribution throughout the mass of milk.

## ADDITION OF COLOR

When color is used, it is added just before the rennet. It is diluted with approximately 20 times its volume of drinking water to insure its even distribution in the milk.

**Amount of color.** The amount of color added depends on the demand of the market for which the cheese is intended. About 1 ounce for 1,000 pounds of milk is generally acceptable, but the amount may vary from one-half ounce to 3 ounces. Different brands of cheese color are not alike in coloring power. Usually one-half ounce in 1,000 pounds of milk gives a light color and one and one-half ounces produces a reddish hue. The natural color of the milk very slightly modifies the amount of color required.

**Method of adding color.** The operator pours the diluted color into the milk in the vat in an even stream while he walks from one end of the vat to the other. Vigorous mechanical agitation of the milk is used to insure uniform and rapid distribution of the coloring material.

Color and rennet should not be mixed together before adding them to milk. Cheese color is an alkaline solution of the coloring matter obtained from the surface of annatto seed. Rennet is inactivated or greatly weakened by alkali.

## ADDITION OF RENNET EXTRACT

Adding rennet extract to milk in cheese making is commonly known as **setting** or **renneting.** The rennet is added when it has been determined that the acid is developing at the desired rate.

**Temperature of milk.** The ideal temperature of raw milk at setting, under normal conditions, is 86°F. Pasteurized milk gives a better curd for subsequent handling when the setting temperature is 88°F. At higher than normal temperatures the curd hardens too quickly to handle conveniently so that there is danger of curd breakage; moisture control may become a problem when high temperatures are used. Lower than normal temperatures require more time to develop the firmness desired for cutting; lack of firmness at cutting causes unnecessary breakage and reduction in yield.

The temperature of the milk must be uniform in all portions of the vat.

**Amount of rennet extract.** Sufficient rennet extract is used to form curd that is firm enough to cut in 25 to 30 minutes after the addition of the rennet. Generally this amount approximates 2.5 to 4.0 ounces of rennet for 1,000 pounds of milk. The principal factors which influence the exact amount of rennet to add to get the proper rate of curd formation are: (1) the strength of the rennet extract; (2) the setting temperature of the milk; (3) the acidity of the milk; and (4) the composition of the milk.

The amount of rennet extract is sometimes increased to hasten the rate of ripening. There is a noticeable increase in the rate of formation of water-soluble proteins in the ripening cheese when more than normal amounts of rennet are used; the body of the cheese tends to be softer. This is not associated with the production of more cheese flavor; excessive amounts of rennet extract tend to cause bitter flavors in the finished cheese.

**Method of adding rennet extract.** The rennet extract is diluted with at least 20 times its volume of pure, cold water. This is done just before the rennet is added to the milk in the vat. The object of this dilution with cold water is to make it possible to distribute the rennet thoroughly and uniformly before it begins to coagulate the casein of the milk.

The diluted rennet is poured slowly into the milk in an even stream, down the center of the vat, from one end to the other. Some operators prefer to pour it into the milk in an even stream, near the sides of the vat, while walking around the vat. It is always good practice to add the rennet solution just ahead of the traveling paddles of the mechanical agitator.

The milk is stirred thoroughly for 3 to 5 minutes after the rennet has been added. While the rennet is being stirred into the milk, that portion of the milk which rests in the gate of the vat is drawn off in a pail and poured back into the vat again. Curd remaining from rennet tests, if it is the same color as the milk in the vat, can be returned to the vat at this time.

The vat is covered as soon as the stirring is ended. This keeps the surface warmer and protects it from stray dust particles.

These operations are so timed that practically all motion of the milk has ceased before coagulation can be visibly detected.

**Signs of coagulation.** There are certain visible indications of rennet action in the milk before flakes of curd can be detected with the naked eye. Bubbles of air, which can be stirred into the surface of the milk by the rapid movement of a thermometer, remain longer before breaking as the milk approaches the point of coagulation. Just before the milk changes to a soft gel, or curd, these bubbles remain unbroken for two seconds and longer. This is the instant when all motion of the milk must have practically ceased. A spatula or thermometer dipped into the milk and withdrawn again at this time shows very small flakes of curd adhering to its surface, instead of the smooth film of milk which would have been there a moment before. This instant in factory practice is regarded as the time of coagulation.

## REFERENCES

Babcock, S. M. (1895). 11th Ann. Rept. Wis. Agr. Expt. Sta., p. 146.

Combs, W. B., Martin, W. H. and Hugglar, N. A. (1924). J. Dairy Sci., *7*, 524.

Fisk, Walter W. and Price, Walter V. (1923). N. Y. (Cornell) Agr. Expt. Sta., Bul. 418.

Hastings, E. G. and Evans, Alice C. (1913). U. S. Dept. of Agr. Bur. An. Ind., Circ. 210.

Hood, E. G. and Hlynka, I. (1946). Nat. Butter and Cheese J., 37, 1:38; 2:39.

Miersch, Raymond and Price, Walter V. (1943). Nat. Butter and Cheese J., *34*, 12:26.

National Cheese Institute (1947). National Cheese Institute, Inc., 110 N. Franklin St., Chicago, Ill.

Price, Walter V. (1927). N. Y. (Cornell) Agr. Expt. Sta., Memoir 105.

Price, Walter V. (1944) Wis. Agr. Expt. Sta., Bul. 464.

Sommer, H. H. (1935). Wis. Agr. Expt. Sta., Res. Bul. 127.

Sommer, H. H. and Hart, E. B. (1919). J. Biol. Chem., *40*, 137.

U. S. Public Health Service (1939). United States Public Health Service. Public Health Bul. 220.

Wilson, H. L., Hall, S. A., and Rogers, L. A. (1945). J. Dairy Sci., *28*, 187.

Wilster, G. H. (1930). Nat. Cheese J., *22*, 11:10.

# CHAPTER 12

# CHEDDAR CHEESE MAKING: CUTTING TO MILLING

## Cutting the Curd

**When to cut the curd.** The curd is ready to cut when a dairy thermometer inserted at a 45° angle will make a clean split in the curd when it is lifted straight up. The split in the curd should look as though it had been laid open by the stroke of a sharp knife. This firmness of curd formation will appear after an interval which is in direct proportion to the time required for the milk to thicken or coagulate. Thickening, or coagulation, is the instant when small flecks of curd can first be detected on a spatula when it is dipped into the milk and withdrawn. In general, the time from adding the rennet until the time of cutting is 2.5 times the interval from adding the rennet to the time of coagulation. This can be illustrated by an example:

Rennet added .......................7:30 a. m.
Coagulation ........................7:40 a. m.

Time for coagulation 0:10 minutes
10 minutes × 2.5 = 25 minutes
7:30 a. m. + 25 = 7:55 a. m., the time of cutting.

The cutting of the curd is started soon enough to avoid excessive hardening before the operation can be completed. A factor of 2.3 is commonly used in working large vats. This means that the cutting begins just before the curd attains the optimum condition for cutting.

When curd is cut too soon, the loss of fat and casein is increased; the yield of cheese is decreased. When the curd is too hard at cutting, it is more difficult to cut into pieces of uniform size. Hard curd tends to delay moisture losses during subsequent making operations.

**Curd knives.** Curd knives like those shown in figures 12:1 and 12:2 are made with frames of tinned steel or stainless steel.

Across these frames are stretched stainless steel wires that are parallel to each other. These wires are usually one-fourth or three-eighths inches apart in Cheddar curd knives.

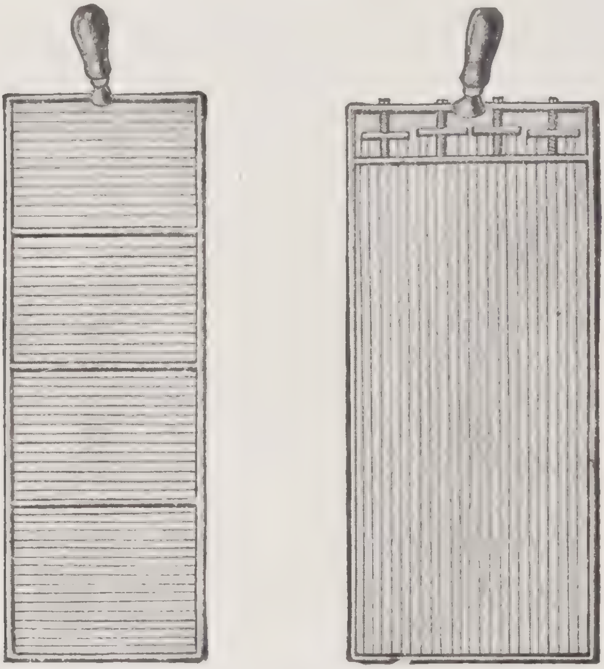


Figure 12:1. Horizontal curd knife (*left*) and vertical curd knife (*right*). (*Courtesy of Creamery Package Manufacturing Company*).

Curd knives are always made and used in pairs for cutting Cheddar curd. One knife of the pair has the cutting wires strung across the frame, and is called the **horizontal knife.** The second knife of the pair is made with the wires strung the length of the frame; it is called the **vertical knife** or the **perpendicular knife.**

Small curd knives may be 8 to 10 inches wide. In recent years wider knives have been used extensively; they are slightly wider than half the width of the vat in which they are used.

**Method of cutting.** The routine of using the knives in cutting the curd is designed to produce the cubes of curd with the least possible breakage. There are three main steps in the cutting procedures: (1) the horizontal knife is used to cut the curd into horizontal layers extending from one end of the vat to the other; (2) the vertical knife is used to cut the horizontal layers into square strips which also extend from one end of the vat to the other; (3) the vertical knife is used to cut across the vat, from side to side, to reduce the square strips of curd into cubes of the desired size. When the wide knives are used, steps (1) and (2) are performed in one operation by two men working together. They stand on opposite sides of the vat, insert both knives edge to edge, and then while holding the edges of the knives together in the center of the vat, each man pulls his knife through the curd to the opposite end of the vat. They exchange knives across the vat and repeat the cutting in the opposite direction. This procedure leaves the curd in square strips extending the length of the vat. The vertical knife is then used in the usual manner to cut across the vat from side to side as in step (3) described above.

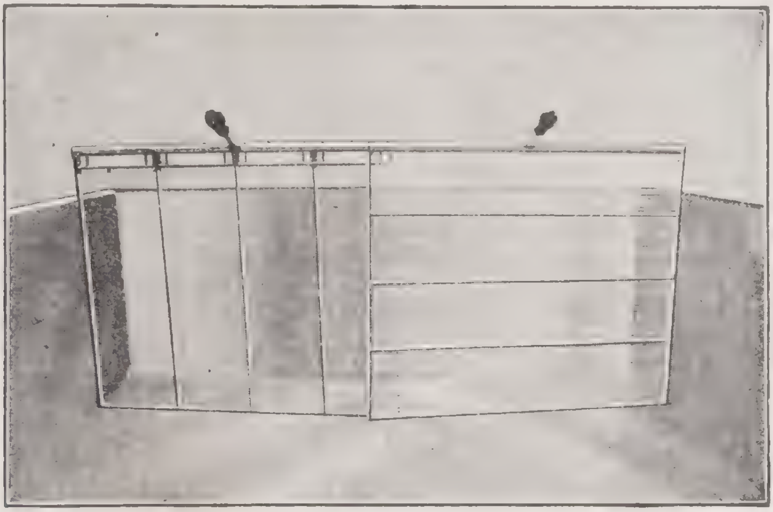
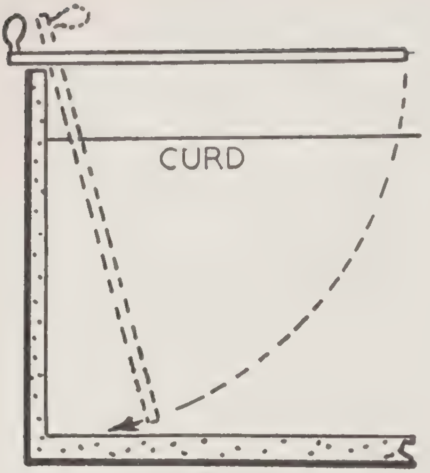


Figure 12:2. Large curd knives. The horizontal knive is at the right, the vertical one at the left. (*Courtesy of Damrow Brothers Company*).

Much of the success of the cutting operation depends upon the skill exercised in handling the knives. Methods of inserting the knives into the curd, moving them through the curd, and removing them from the curd, are described and illustrated in figures 12:3 and 12:4.

**Size of cubes.** Cheddar cheese is usually made with curd knives which reduce the curd to one-quarter inch or three-eighths inch cubes. Rarely, smaller or larger knives are used. The effect of small knives is to release the whey more completely and rapidly. For example, cubes cut by one-quarter inch knives attain the desired firmness more than twice as fast as cubes made with one-half inch knives. This relationship is used to remove

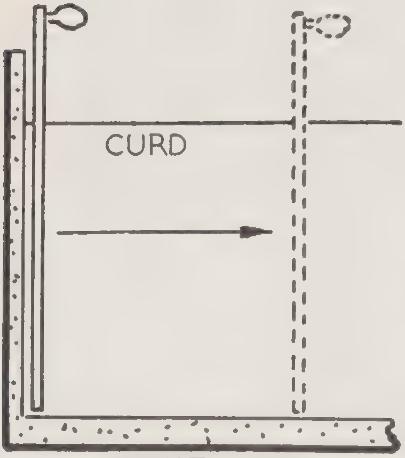


INSERTING

Figure 12:3.

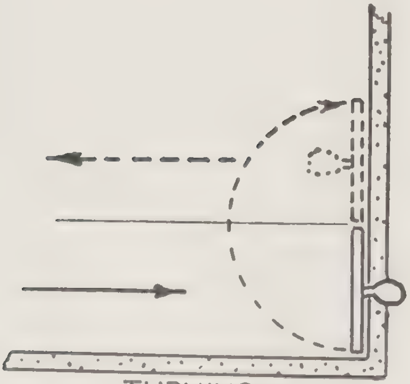
Using the horizontal knife to cut the curd into layers

a) *Inserting.* Lay the knife on the end of the vat so that enough of it projects over the curd to reach the bottom of the vat. Swing the knife down into the curd, using the top edge of the vat as the fulcrum. Bring the knife to rest squarely against the end of the vat. The handle points in the direction of the cut to be made.



CUTTING

b) *Cutting.* Hold the horizontal knife straight up and keep the end of the knife on the bottom of the vat. Walk beside the vat holding the edge of the knife so that it rubs against the side of the vat while making this first cut.



TURNING

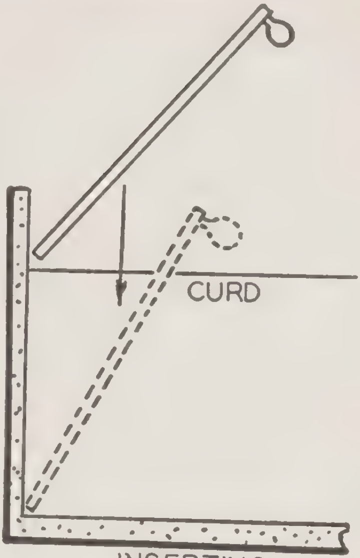
c) *Turning.* Bring the knife squarely to the end of the vat. Use the corner of the knife as the pivot point and rotate the knife *away* from the side of the vat and through a half circle so that the handle points back in the direction from which the cutting started. Return the knife through the curd so that it does not overlap the first cut nor leave any uncut portion between the strips. Repeat these operations until all of the curd has been cut into horizontal layers.

d) *Ending.* When the last cut ends, the knife rests against the end of the vat. Remove it from the curd by reversing the motions used in inserting it into the curd. This is done by swinging the knife up and out of the curd, using the edge of the vat as the fulcrum.

Figure 12:4

Using the vertical knife to cut the horzontal layers into square strips and cubes.

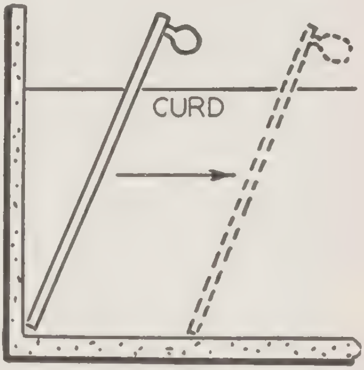
a) *Inserting.* Hold the vertical knife at an angle to the end of the vat, and slide the end of the knife down the end of the vat "between" the curd and the metal. Rest the end of the knife against the bottom and end of the vat to begin the cutting.



INSERTING

b) *Cutting.* Hold the edge of the knife against the side of the vat while making the first cut. Walk briskly to the opposite end of the vat so that the knife slices through the curd with a minimum of curd movement.

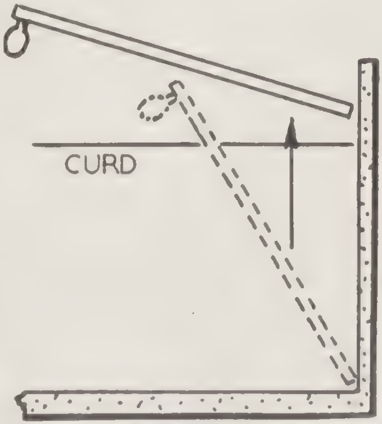
c) *Removing.* Bring the bottom of the knife into contact with the bottom corner of the end of the vat and then lift the knife up and out of the curd. Keep the end of the knife against the end of the vat so that all of the curd is cut as it slips through the wires.



CUTTING

d) *Repeating.* Rotate the knife, reach toward the center of the vat, and insert the knife into the curd as described in (a). Begin the return cut so that it neither overlaps the first cut nor leaves uncut areas between them. Repeat until finished.

e) *Cutting strips into cubes.* Stand at the side of the vat and reach across it with the vertical knife. Insert the knife in the manner described in (a), draw it quickly across the vat as in (b), and end the cut by removing the knife as shown in (c). Repeat these slicing operations until all of the strips have been reduced to cubes.



REMOVING

whey from curd at a rapid rate; this may be necessary in handling overripe milk.

The vertical knife may be used to slash the curd into smaller than normal pieces. Such a practice helps eliminate the whey by reducing the size of curd particles, but it also causes excessive losses of fat and casein in the whey, and introduces the problems of irregularity of shape and size of curd particles.

Rate of heat transfer through curd is an essential factor in regulating the size of curd particles. Large pieces of curd require longer for complete heating; the whey escapes from them more slowly. If it is the desire of the operator to use larger knives in cutting, then the rennet must be added when the milk shows less acid development, in order to allow the curd to remain in the whey long enough to become properly firmed before dipping. Such adjustments are commonly made and explain unusual differences in the operations of different factories.

**Behavior of curd after cutting.** After the curd is cut, whey begins to appear between the cubes; a slight coating or film begins to form on the outer surface of each cube. The existence of this film can be shown by breaking one of the cubes and holding it so that light reflects from the broken surface. It is important that this film should not thicken or harden too rapidly and thus prevent the escape of whey at the desired rate. Care is exercised in subsequent operations to avoid breaking this film, because, when it is broken, fat and casein escape from the softer interior of the curd and are lost in the whey.

The operations which follow immediately after cutting are designed to control the expulsion of whey and the development of firmness in the consistency of the curd particles. The contraction or hardening of the pieces of curd, as they lose their first jelly-like consistency and acquire increased solidity and elasticity, is known as **firming.**

**Acidity of whey after cutting.** The whey immediately after cutting contains 0.05 to 0.08 per cent less titratable acidity than the milk at the time of renneting. This is because the curd contains practically all the casein and a portion of the phosphates. These two substances, which are capable of combining with the alkali of the titration test, are no longer present in the whey to react with the alkali when the whey is tested for acid by titration.

Measurements of pH of curd and whey at cutting show that acid development is proceeding at the rate to be expected from pH measurements of the milk before the rennet was added.

## STIRRING CURD AFTER CUTTING

Acidity tests are made on the whey, or curd, or both, immediately after cutting. During the two- or three-minute interval required for these tests the curd need not be stirred. Free whey quickly appears between the cubes of curd and the curd tends to sink slowly. Agitation should begin at this point.

**Beginning of stirring.** The stirring operation begins when the curd sticking to the metal sides and bottom of the vat is gently removed. This can best be done with a flexible, stainless-steel blade fixed to a sanitary handle. This operation of removing the curd tends to prevent sticking of curd to the vat during the heating operation to follow.

**Mechanical agitation.** As soon as the sides and bottom of the vat have been wiped free of any adhering curd, the mechanical agitators can be started on slow speed. Agitation is usually started within three to five minutes after the end of cutting. The speed of agitation is gradually increased as more free whey is expelled from the curd particles. Matting together of the pieces of curd indicates inadequate speed or improper stirring in all portions of the vat. It may be necessary in vats with square ends to stir out the corners with a curd rake. Some mechanical agitators can be held at the ends of the vat momentarily and so will sweep out the corners fairly efficiently without hand stirring. If curd tends to mat in all parts of the vat, the agitation is too gentle. Agitation should not be vigorous enough to break the curd in a normal operation.

Uncut curd that remains in the gate opening of the vat is drawn off at this time and poured back into the vat.

## HEATING THE CURD

**When to apply the heat.** Heating or "cooking" of the curd begins within 15 minutes after cutting. At this time there should be enough free whey in the vat to "float" the curd, that is, to keep it from direct contact with the sides and bottom of the vat when it is being stirred. The combined influence of heat, rennet and acidity determine the rate at which the free whey is released by curd particles of a given size. Since the temperature of the curd at cutting and the amount of rennet used at setting are both relatively constant, then the differences in the acidity will account largely for differences in rate of whey formation. Under the conditions established in the making of Cheddar cheese, the formation of free whey is fairly rapid within the first 10 minutes after cutting. It proceeds more slowly during the next few minutes. The application of heat to the contents of the vat has the immediate effect of stimulating the release of whey by the curd.

**Regulation of heating.** The heat is applied slowly at first because raising the temperature too rapidly causes the formation of a thick film around each piece of curd; such a film prevents normal release of whey. If too much whey is retained in the curd, for this or any other reason, the cheese will tend to be acidy or sour.

The temperature of the curd and whey is raised 2°F. in the first 7 minutes of heating and 2°F. in the next 5 minutes. After the temperature reaches 90°F. the rate of heating can be increased to 3°F. in every 5 minute period until the maximum temperature of heating has been attained.

When acid is developing faster than the desirable rate indicated in table 11:1, then a faster rate of heating is necessary. The minimum time of heating such an abnormal vat approximates 20 minutes. It is impossible to do this properly unless the amount of agitation is adequate to keep the particles of curd from matting together.

When heat is first turned on, there is an increase in the tendency of the curd particles to mat together. If the agitation is inadequate, the curd particles will form lumps or aggregates of curd. Such formations are indicative of slow stirring, excessively fast heating, or incomplete stirring of the curd in the corners of the vat where it is heated most rapidly and stirred least vigorously by mechanical agitators.

Three or four times during the heating of the vat, the curd in the gate of the vat is drawn off in a pail and poured back into the vat.

**How high to heat curd.** Milk of average composition containing approximately 3.5% fat is usually properly heated if the maximum temperature attained in the normal length of time is 100° to 102°F. Composition of milk and acidity must be considered in deciding the ideal treatment.

The fat content of milk influences the rate of release of the whey. Milk with less than average amounts of fat produces curd that loses its whey more easily; curd made from milk that is rich in fat, on the other hand, tends to retain its moisture more tenaciously. It is customary in making Cheddar cheese from low-fat milk to use a heating temperature of 98° to 100°F.;

when high-fat milk is used then the temperature of heating is usually increased to 102° to 104°F.

The curd in which acid is developing very slowly is better when heated to a temperature one or two degrees lower than would normally be used. This slightly stimulates acid production because the action of the starter organisms is usually somewhat faster at cooking temperatures less than 100°F. Loss of whey from curd is increased by lengthening the holding period at the maximum temperature as well as by increasing the maximum temperature itself. This is the second reason why the maintenance of a lower temperature in heating a curd with slow acid development tends to produce a cheese of better quality. When curd is developing acid more rapidly than seems desirable then the maximum temperature of heating is recommended. When the temperature of heating exceeds 104°F., then the activity of *Streptococcus lactis*, the chief acid-producing organism, is decreased. This is an additional factor by which the acid development in the curd and cheese can be controlled. Temperatures as high as 110°F. are occasionally used for this purpose. Excessively high temperatures of heating and undue prolonging of the heat treatment tend to produce corky bodied cheese.

The temperature attained during heating is maintained until the curd is ready to remove from the whey. A drop of two degrees in temperature tends to delay firming of the curd. Excessive drops in temperature, that can occur in a cold making room, may actually cause the partially firmed curd to take up moisture. Acid development may be retarded by falling temperatures.

Stirring of the curd after the maximum temperature has been attained must be continued until the temperature of the curd is uniform; this usually requires 5 to 10 minutes. Stirring after this time may be intermittent or at slow speed but must keep the curd from matting together until it is settled for dipping.

## REMOVAL OF WHEY

The operation of removing the whey from the curd is called **dipping**. In the early days of making Cheddar cheese the curd was actually dipped from the vat with a pail or scoop and poured into a rack covered with a draining cloth.

**Settling the curd.** At about one hour and three-quarters after adding the rennet, normal curd begins to show the characteristics it should have at the time of dipping. The curd begins to feel elastic, the size of the particles of curd are a little more than one-half the size they were at cutting, and the acidity development is approaching the desired limit. At this time, the stirring of the curd is stopped and the curd is allowed to settle to the bottom of the vat. In two or three minutes the curd can be pushed away from the gate of the vat with a rake. A gate strainer is inserted in the gate, a curd pail is hung on the gate outlet, and about half of the whey is drawn from the vat.

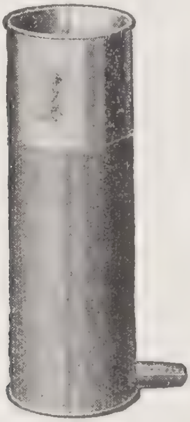


Figure 12:5 Gate strainer. *(Courtesy of Oakes and Burger Company).*

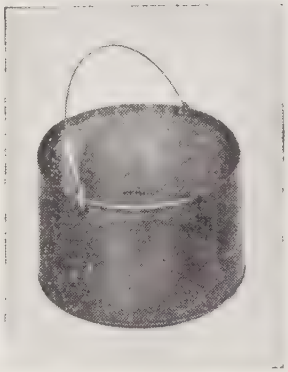


Figure 12:6. Gate pail or strainer curd pail. *(Courtesy of Damrow Brothers Company).*

This removal of a portion of the whey before the curd is quite ready to dip makes it possible to remove the remainder of the whey more quickly when the proper time is reached. The titratable acidity of the whey remaining in the vat apparently shows a more rapid rate of increase. This is because acid is being formed faster inside the curd particles than it is in the whey outside the curd. There is less sweet whey in the vat to dilute the whey continually released by the curd so the acid development appears to increase at a more rapid rate. Actually the hot iron test and pH measurements of acidity in the curd do not show any sudden increase in acidity associated with the partial removal of whey.

**Condition of curd at dipping.** About two to two and one-fourth hours after adding the rennet the curd shows the characteristics required for dipping. The curd particles are approximately one-half as large as they were at cutting. A handful of the curd feels firm and somewhat elastic when squeezed. A double handful of curd, pressed gently and momentarily into a ball, springs apart when held in the palm of one hand. When the hand is moved through the curd in the whey, the curd feels like little pellets of shot. The curd particles have no soft centers.

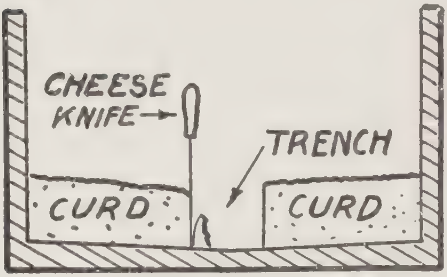
The hot iron test at the time of dipping shows one-sixteenth of an inch of the fine silky threads that are associated with the development of acid in the curd. More than one-eighth of an inch of these threads is an indication of excessive acid development.

The titratable acidity of the whey at this time is commonly used to measure the acid developed. It is impossible to state definite values that will be reliable and useful to every operator who follows the practice of draining a portion of the whey from the vat before he is ready to complete the dipping operation. If the same practice is followed day after day then the operator will find that the acidity of the whey will be fairly regular and fairly reliable. It will range about half way between the acidity of the milk at the time of setting and the acidity of the whey at the time of cutting. If all of the whey is removed from the vat within a period of 30 minutes, then the acidity two hours after setting should be from 0.02 to 0.04 per cent more than it was at the time of cutting.

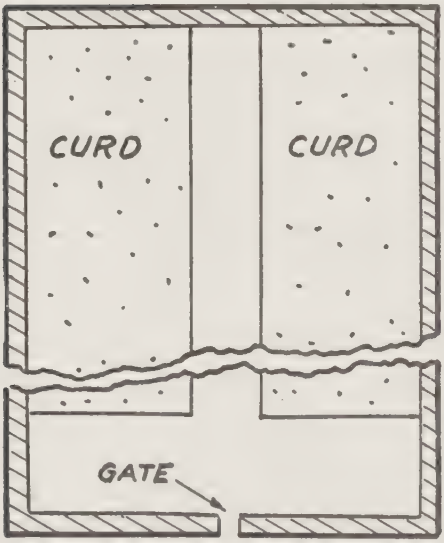
The pH of the curd at dipping is very close to 6.1 when the time of dipping is two and one-quarter hours after adding the rennet.

Under normal conditions, when the making process is under complete control, about two and one-quarter to two and one-half hours elapse between the adding of rennet and the dipping of the curd. Sometimes the desired firmness, or acidity, or both, may develop either too slowly or too rapidly. When the curd is firm but lacks acidity, or when the curd lacks both firmness and acidity at the proper time for dipping, then the curd can be held until both firmness and acidity have been attained. If the proper firmness develops ahead of the acidity, then delaying until the desired acidity is attained will give cheese with low moisture content. When the desired acidity is attained too soon, or before the proper firmness has developed, then the situation is more serious, and may cause sour cheese. The remedy is discussed in Chapter 15 under the heading of "Acid cheese." The prevention of this condition in subsequent vats is to reduce the rate of acid development in the milk at the time of adding the rennet.

**Dipping.** The quantity of whey remaining in the vat, and the speed with which whey can be drawn from the vat, will determine the time before dipping when the remainder of the whey is started from the vat. The removal of the last of the whey from the curd must coincide: (1) with the attainment of the ideal characteristics of the curd in terms of firmness and acidity, and (2) with the expiration of the time limit allowed for the development of these characteristics.



SQUARING EDGES



CURD AT DIPPING

Figure 12:7. Systematic arrangement of the curd at the time of dipping is essential for controlling temperature, acidity development and composition.

In the final stages of draining the whey from the curd, the curd must be arranged in the vat in preparation for the next stage of making. As the whey is being drawn from the vat, a trench in the curd is worked down the center of the vat. This is done by carefully pushing the curd from the center toward the sides of the vat with the back of a curd rake. The curd is also pushed back from the gate end of the vat. The depth of the curd is equalized as much as possible in all sections of the vat.

As the whey is withdrawn, the curd is exposed. This stage of the operations is shown in figure 12:7. The edges of the trench are rough so a cheese knife is used to cut away these edges and the pieces of curd and crumbs are thrown back over the curd at the sides of the vat. After this trimming, the trench should be 12 to 18 inches wide, depending on the width of the vat. When the bottom of the vat in the trench is uncovered by the removal of the whey, the dipping operation is said to be complete. At this time the whey is still running freely from the curd and the curd is settling in two, long, level slabs, one on each side of the vat. These slabs are approximately 8 inches thick

20 inches wide and usually about 3 feet shorter than the vat itself, if the vat was full of milk at the time of setting.

**Stirring of curd at dipping.** The dipping operations that have been described are those generally followed in modern practices in the United States. In previous years makers hand-stirred or forked the curd vigorously just before, or while, the last of the whey was being removed from the vat. Such stirring keeps the curd particles from matting and helps the free whey escape more rapidly. Prolonged stirring delays the matting of the curd in the cheddaring process that follows. For this reason, and also because of the hand labor involved, the practice has practically disappeared in factories in the United States.

If the operator chooses to stir the curd at the time of dipping, it is desirable to start the stirring when the receding whey first exposes the top of the curd in the vat. Stirring continues until the operator is satisfied that he has attained the correct firmness and color of curd. If the curd has not previously been properly firmed, then vigorous hand stirring or forking may break the particles of curd and cause serious losses of fat and casein. Hand stirring or forking gives a brighter color to the curd. The treatment is commonly used to make low moisture cheese, and to develop firmness of curd when the acidity is slightly higher than desired at the time of dipping.

As the stirring of the curd is ended, it is trenched and distributed along the sides of the vat in the manner that has already been described.

## CHEDDARING THE CURD

The combined operations of packing, turning, piling and repiling the curd are known as **cheddaring**. This series of operations, which lasts for approximately two hours after dipping, is the distinctive characteristic of the cheddar method of making cheese.

The cheddaring operations have two objectives: (1) to control the moisture content by regulating the removal of whey; and (2) to form the characteristic body and texture in the curd.

**Packing.** The curd at the end of dipping is still somewhat loose and granular, but it settles together rapidly as the free whey escapes from the two, long slabs at the sides of the vat. The thickness of the slabs of curd at this time is usually one or two inches less than at the time of dipping.

The packing operation begins when these slabs of curd can be sliced into blocks and rolled over without breaking. Lifting the edge or corner of a slab an inch or two off the bottom of the vat will show when it has attained the necessary solidity.

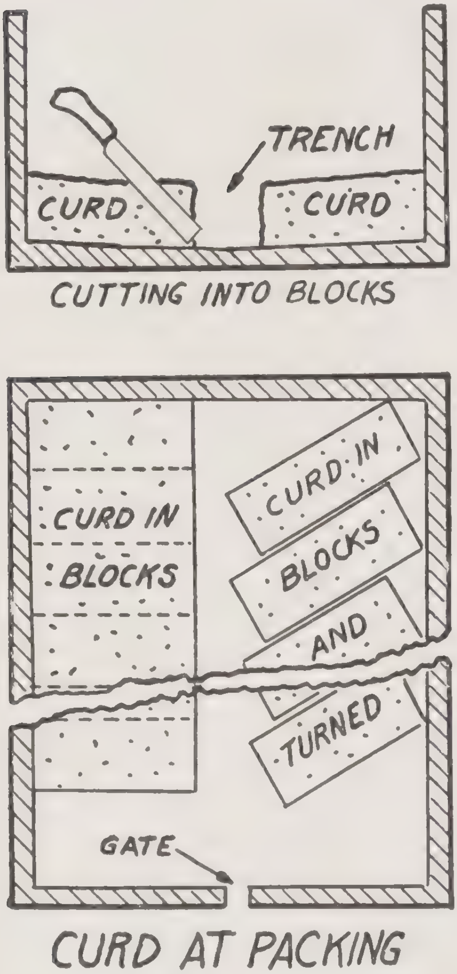


Figure 12:8. Cutting the layers of curd into blocks of uniform size and shape, simplifies the attainment of the objectives of the cheddaring operations.

**Time of packing.** The interval between dipping and packing is usually not less than 5 minutes nor longer than 15 minutes. If the curd is allowed to settle and drain without agitation during the removal of the whey, then the shorter interval will suffice. Stirring of curd just before dipping, or during the removal of the last of the whey, may prolong this interval beyond the 15 minute limit.

**Cutting the slabs into blocks.** The two slabs of curd at the sides of the vat are cut with a cheese knife into blocks or strips about 6 to 8 inches wide. These operations are shown in figure 12:8. These cuts are made at right angles to the sides of the vat. The blocks formed in this way are approximately 6 inches thick, 6 to 8 inches wide, and 20 inches long. As soon as they can be handled without breaking, the blocks of curd are rolled bottom-side-up in the vats. The first blocks of curd to be turned are the ones nearest the gate end of the vat. As each block is turned, it is moved away from the unturned blocks so that space is provided between all blocks for the whey to escape more readily. Pointing the blocks slightly toward the gate facilitates drainage in some vats.

**Acidity at packing.** The acidity of the whey at packing is the same as that of the milk at the time of setting. This represents an increase of approximately 0.07% over the acidity of the whey at cutting. The hot iron test of the curd is the same or very slightly more than it was at dipping, that is, one-sixteenth of an inch. The pH of the curd is the same or slightly more than that of the curd at dipping. Table 11:1 shows these values in relation to the recommended time schedule of making.

**Turning the blocks.** The blocks of curd are turned completely over at intervals of 15 minutes. This turning is repeated every 15 minutes until the curd is ready for milling and salting. All loose crumbs of curd left on the bottom of the vat after each turning of the curd are carefully pushed under the blocks of warm curd to which they adhere quickly. If these crumbs are placed on top of the curd or are left scattered about the vat, they become dry and hard and may cause defective body or finish in the cheese. The cheese vat is kept covered between turnings to maintain the proper temperature and to prevent airborne contamination of the curd. For best results the temperature of the curd is kept above 90°F. while it is being turned.

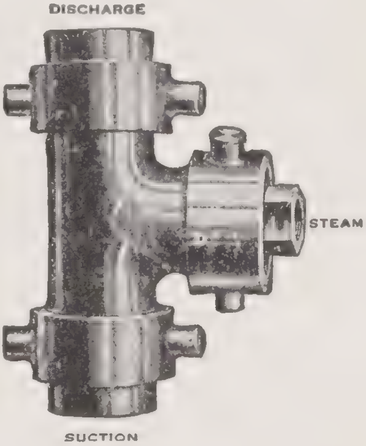


Figure 12:9. Sanitary steam jet for lifting and heating whey. *(Courtesy of the Creamery Package Manufacturing Company).*

**Piling the blocks.** In 30 to 45 minutes after packing, the blocks are turned and piled two high. At this time there is very little free whey draining from the curd; the temperature of the curd is four or five degrees less than at the time of dipping.

When the curd is ready to pile two high, the blocks are about 24 inches long and 3 to 4 inches thick. It may be more convenient to handle them if they are cut into two blocks about 12 inches long. In piling these cut pieces, the freshly cut ends are faced toward the center of the vat.

The blocks are turned again after the usual 15 minute interval and piled two high. Cool ends and surfaces are piled next to warmer surfaces; blocks from the top layer are placed in the bottom layer. In this way the temperature of all the curd is kept more uniform.

At 30 to 45 minutes after piling the blocks of curd two high, they are turned again and piled in three layers. Fifteen minutes later they are repiled in three layers. Occasionally the blocks of curd are piled more than three high. These are unusual treatments which are applied for purposes of moisture control or for the control of the texture of the cheese.

**Cheddaring for moisture control.** The temperature, acidity, and probably the continued action of rennet, influence the tendency of the curd to lose moisture during the cheddaring operations. Of these three, temperature is the factor which can be most readily controlled during cheddaring. Rate of acid development and rennet action are influenced by variations in temperature. Higher temperatures tend to encourage more loss of moisture from the curd; if they are too high, the curd becomes greasy, and imperfect rind formation develops.

The cheddaring operation provides mechanical methods of moisture control. These manipulations are: the depth of the curd at dipping and packing; the size of the blocks of curd at packing; the frequency of the turning of the blocks of curd; and the time and height of piling. Those variations which tend to retain more moisture in the curd are: thicker slabs of curd at dipping and packing; larger blocks of curd at packing; infrequent turning of the curd; and early piling and high piling of the curd. These manipulations affect the ease with which whey can escape from the curd. Increasing the depth of curd at packing, for example, delays loss of whey by increasing the distance between the center of each block and the surface from which it escapes. Piling of the curd, especially when it is high in moisture content in the early stages of cheddaring, has the same essential effect. Reversing these manipulations which cause the curd to retain moisture, reduces the moisture content of the cheese.

**Cheddaring to control body and texture.** At the time of packing, the curd has a tough, rubber-like body. As the cheddaring operation proceeds, the curd loses some of its toughness and becomes more plastic. At the same time the surfaces of the blocks become smoother and softer. At packing, blocks of curd have a tendency to crumble and break; at the end of cheddaring, these blocks bend without breaking, much like slabs of meat.

There is an interesting change in the interior of the blocks of curd during cheddaring when the blocks flatten out and become about half as thick as they were at packing. Part of this is caused by the packing together of the curd particles through loss of whey; part of it, however, is caused by the stretching of the blocks. If a properly cheddared block of curd is turned on edge and torn in half, the curd will tend to tear apart in fibrous shreds. Close examination of these shreds will reveal that they consist of the greatly flattened and elongated particles of curd which overlap each other and cling together.

The physical changes in body that take place during cheddaring are the results of chemical changes produced by increasing formation of lactic acid. Briefly stated, the lactic acid combines with the calcium of the calcium paracaseinate of the curd converting it into forms containing less calcium. The length of strings of curd in the hot iron test are evidence of the extent of this reaction.

The texture, that is, the presence of openings in the finished cheese, can be attributed in part to the treatment of the curd during the cheddaring operation. If a block of curd is cut in two a few minutes after packing, many irregularly shaped holes will be seen in the cut surface. These openings evidently are associated with the extent of the compacting of the curd particles. If a block of the same curd is cut in two after cheddaring, there are few, if any, openings in it. The disappearance of these openings is directly related to those physical changes associated with the development of the plasticity of the curd.

When gas-forming organisms contaminate the curd in large numbers, they may form holes in the curd. These holes are small, sometimes scarcely visible to the naked eye, round or egg shaped; they are easily distinguished by their small size, regular shape, and large numbers from the irregularly shaped holes associated with the compactness of the curd. When such gas holes appear during the cheddaring operation, the maker usually extends the period of piling and repiling until the holes tend to flatten out and close up. This type of openness in cheese is an abnormal condition and if it is not properly treated it will produce similar holes and other defects in the finished cheese. The treatment of this defect is considered in Chapter 16 under the heading of "Gassy texture."

**End of cheddaring operation.** In a normal cheddaring process the desired changes in the curd are completed in approximately two hours after dipping. This period is extended when a cheese with lower moisture content, and very close texture is desired.

The acidity of the curd at the end of cheddaring can be measured by titration of the whey, by the hot iron test, and by measurement of pH. Two hours after dipping, the whey draining from the curd should have 0.30% to 0.35% more acid than at the time of cutting; for example, when the titration at cutting is 0.10%, the acidity at milling approximates 0.40%. The hot iron test of this curd should be one-half inch or slightly more; and the pH measurement of the curd should approximate 5.4. When the cheddaring operations are extended beyond two hours, the development of acid is correspondingly increased.

The body of the cheese at the end of the cheddaring operations is plastic, smooth to the touch, and can be torn apart in thin, meaty shreds or strips.

The texture of the curd, revealed by cutting it crosswise with a sharp knife, should be reasonably free of mechanical openings, and if gas holes are visible, they should be flattened or partially closed.

The temperature of the curd should approximate 90°F. at the end of the cheddaring operation.

## MILLING THE CURD

When the cheddaring process is complete, as determined by the characteristics of the curd, the curd is ready to mill. **Milling** is the mechanical operation of cutting the blocks of cheddared curd into pieces approximately five-eighths of an inch square and two inches long. Thicker blocks of curd yield longer pieces of curd after milling.

The machine used to cut the curd into these small pieces is called a **mill.**

**Purposes of milling.** The primary purposes of milling curd are: (1) to promote the further removal of whey; (2) to make it possible to distribute the salt quickly and uniformly throughout the curd; and (3) to prepare the curd for pressing into its final form. Other benefits are derived from the milling procedure: (1) undesirable odors tend to escape from the curd; (2) the curd is cooled; (3) the curd can be more thoroughly rinsed or washed with warm or cold water for certain special effects; and (4) the composition of the cheese can be made more uniform by mixing together the curd from all portions of the vat.

**Curd mills.** There are several types of curd mills. They may be operated by hand but usually they are power driven. They are made in several sizes to suit the needs of the factory. All good mills cut the curd into pieces of uniform size and shape. They do so with a minimum of crushing or squeezing.

**Method of milling.** At the start of the milling operation, the curd mill is laid across the upper end of the vat, that is, the end away from the gate. The curd is repiled on the side of the vat where the operator will stand to feed the mill. The space under the mill and between the mill and the upper end of the vat is free of curd: the milled curd will fall into this clear area.

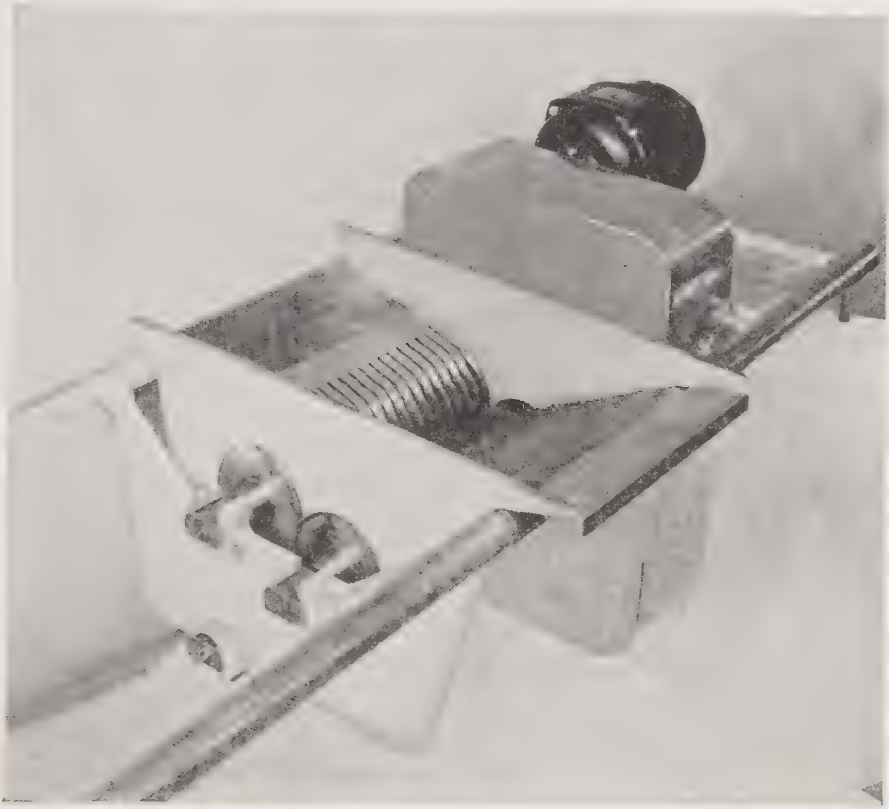


**Figure 12:10. Curd mill.** *(Courtesy of Damrow Brothers Company).*

As the blocks are repiled, they are cut, if necessary, so that they can be fed into the mill without pushing or squeezing them to make them fit.

As the pieces of milled curd fall into the vat, they are stirred over gently by hand fork or mechanical agitator: this is necessary to keep them from knitting together again. As the milling of the curd progresses, the curd mill is moved along the vat toward the gate end: this exposes more cleared area for distributing and stirring the curd, and brings the mill nearer the diminishing pile of unmilled blocks.

Stirring of the curd is continued during and after milling: the stirring may or may not be continuous. The agitation must be sufficient to keep the curd from matting until the operator is ready to apply salt. It should not be so vigorous and prolonged that the curd is unnecessarily broken or made greasy.

**Losses in milling.** Milling normally releases a small amount of whey from curd. The curd mill opens up the original curd particles and exposes fat globules in the freshly cut surfaces. The fat is in a fluid condition at the usual temperature of milling so it tends to escape with the whey or, if there is very little of it, it may merely tend to form a film of fat on the surfaces of the curd particles. If conditions of manufacture up to this point have been normal, the losses of whey and fat will be relatively small. Milk of inferior quality, improper heating, lack of firmness at dipping, fast piling and high piling during the cheddaring operations, and excessive acid development, all tend to increase the losses of whey and fat at this time. "White" whey, which may run from the curd at milling after faulty or careless making operations, is rich in fat and milk solids-not-fat. Such losses decrease the yield of cheese.

Curd may be rinsed with water after milling to improve its physical condition for salting and pressing. If the curd tends to be greasy, it should be rinsed with water at a temperature slightly less than that of the curd. The object is to remove the fat and to chill the curd slightly to check further fat losses. If the curd is too cold at this time it may be rinsed with warm water so that it will knit together better during the pressing operation. Such water treatments are accomplished by spraying the curd lightly with a minimum amount of water and so stirring and trenching the curd that the water runs quickly from the vat. This is not the treatment described in Chapter 14 for making "Washed-curd" cheese.

**Holding before salting.** Usually in not less than 15 minutes after milling, the curd particles show only a slight tendency to stick together. During this interval the curd may have been rinsed with water and drained; little or no rinse water or whey remains to escape from the curd. The temperature of the curd approximates 88 F. to 90 F. When these conditions have been satisfied, the curd may be salted.

Salting may be further delayed when it seems desirable to develop more acid, to encourage further drainage of whey or rinse water, or to aerate the curd to improve its flavor.

In the interval before salting, any treatment of the curd that will encourage the exudation of fat from the curd surfaces is detrimental to the appearance and finish of the cheese. The appearance is affected because such fat accumulates on the curd and causes seaminess of color. The finish is injured when the fat collects in the surface openings of the curd during pressing and prevents the knitting together of the pieces of curd in the rind. Such cheese checks or cracks easily and consequently is very susceptible to mold growth and insect infestations. Excessive forking and heating of the milled curd are two treatments which encourage undesirable loss of fat before salting.

## CHAPTER 13

# CHEDDAR CHEESE MAKING: SALTING TO SHIPMENT

### SALTING

**Purposes of salting.** Salt in cheese affects flavor, body, texture, and keeping quality. While salt is added mainly for the sake of quality characteristics, it produces other specific effects, such as: (1) aiding in removal of whey; (2) hardening and shrinking the curd; (3) retarding the formation of lactic acid; and (4) checking undesirable forms of fermentation.

Unsalted cheese breaks down rapidly in body; the cheese flavor is not normal. Excessive salting makes cheese hard and harsh in body; such cheese is drier and cures more slowly than a product with normal salt content.

The addition of more than ordinary amounts of salt is a common practice when the quality of the curd at the time of milling is inferior. The presence of excess moisture, excess acidity, evidences of gas development, and off flavors in the curd, are commonly regarded as signs of inferiority demanding more salt. The addition of salt under such circumstances has a threefold effect: (1) it encourages loss of whey; (2) it tends to inhibit salt-sensitive, undesirable organisms; and (3) it establishes the proper conditions for development of those organisms required in the ripening of the cheese. Salt tends to retard acid development whenever the concentration exceeds approximately one per cent. Hoecker and Hammer (1944) were able to measure this effect of salt by observing the differences in pH of the interior and the surface layers of the curd at pressing.

**When to salt the curd.** Successful cheese makers disagree on the most desirable time for salting curd. There is general agreement, however, that it should not be salted immediately after milling. It takes at least 15 minutes after milling for the curd to develop the silky, mellow feeling that many makers expect before salt is applied. After such an interval the curd can be salted without causing excessive losses of fat.

Acidity measurements are sometimes used as indications of the proper time of salting. At the time of salting, the hot iron test ranges from one-half to one and one half inches, the titratable acidity of the whey may vary from 0.4 to 0.7%, and the pH values approximate 5.4 to 5.0. The lower acidity values correspond to those expected when the making schedule in table 11:1 is followed.

The New Zealand workers have been particularly diligent in studying the salting effects. Dolby (1941) found that the body of 14-day-old Cheddar cheese was improved by salting at lower acidities. Riddet, et al (1933) found that cheese salted at full acidity were better in quality than those salted at once or within 20 minutes after milling.

**Amount of salt.** The amount of salt used depends on the amount of curd in the vat, the salt content desired, and the condition of the curd. Each of these factors needs some explanation:

The amount of curd in the vat depends upon the composition of the milk and the moisture content of the curd. The moisture content at salting is fairly constant for any given factory procedure, although it may vary more than 5%; 40 to 42% is a common range when a cheese with 37 to 38% moisture is being made.

TABLE 13:1. AMOUNTS OF SALT

| *Fat in milk* | *Curd with 40% moisture * from 1000 pounds of milk* | *Salt per 1000 lb. milk* | | |
|---|---|---|---|---|
| | | *Light salting* | *Normal salting* | *Heavy salting* |
| % | lb. | lb. | lb. | lb. |
| 3.0 | 87 | 1.7 | 2.2 | 2.6 |
| 3.2 | 92 | 1.8 | 2.3 | 2.8 |
| 3.4 | 97 | 1.9 | 2.4 | 2.9 |
| 3.6 | 102 | 2.0 | 2.5 | 3.1 |
| 3.8 | 107 | 2.1 | 2.7 | 3.2 |
| 4.0 | 111 | 2.2 | 2.8 | 3.3 |
| 4.2 | 117 | 2.3 | 2.9 | 3.5 |
| 4.4 | 121 | 2.4 | 3.0 | 3.6 |

* The moisture content of the cheese will be about 2% less than that of the curd.

Table 13:1 suggests amounts of salt required for light, normal, and heavy salting of curd from milks of varying composition. The application of this table can only lead to approximations of the desired amounts of salt in the cheese because the methods of applying salt under different conditions affect the amounts absorbed. If they are properly applied, the amounts of

salt in the "Light salting" column of table 13:1 should incorporate at least 1.4% of salt in normal cheese.

The salt content desired in Cheddar cheese approximates 1.5%, but values commonly range from 1% to 2%. Riddet, et al. (1933) observed that New Zealand cheese of normal body contained an average of 1.66% salt which was equivalent to 4.82% salt in the moisture content of the cheese. They found that, with normal moisture content in the curd, salting at 2.25% of the weight of curd at milling gave less open texture and better body than salting at 3.25 or 4.25%. Undersalting produced pasty, weak body, open texture, and abnormal ripening; oversalting produced harsh body, slow ripening, close texture and cracked rinds.

Marquardt and Resi (1940) measured the salt contents of cheese exhibited in a scoring contest. Of 148 entries of different styles of Cheddar, two-thirds of them contained 1.4 to 1.7% salt.

Tuckey and Ruehe (1940) associated the production of bitter flavor in Cheddar cheese with salting treatments that only incorporated approximately 1.3% salt in the cheese; the defect was never found when salt values were 1.7% or more.

Higher than normal salt values are usually found when cheese is made for some special purpose, such as processing. Such cheese is usually purchased on the basis of its dry matter content and it is presumed that it may be subjected to an extended period of curing; the extra salt increases the dry matter content of such cheese, and certainly does not impair the keeping quality. Excessive salt content delays ripening.

The condition of the curd itself affects the degree to which salt is retained. Less salt is absorbed when the surfaces of the curd particles are wet with whey or water. This may occur when the curd is high in moisture, and when it is salted too soon after milling or washing. Some makers save the salty whey and water draining from wet curd in order to pour it back on the curd again. This procedure is least effective when the greatest amounts of whey continue to drain from the curd after salting.

**Kind of salt.** Salt of coarse grain is preferable; it dissolves more slowly and penetrates more completely because it is in contact with the curd longer. It should be free from lumps. Spain (1942) stated that impurities like magnesium and calcium chlorides tend to make salt lumpy in damp weather and give the salt a bitter taste. Salt must be clean and free from extraneous matter. It should be held in rodent-proof storage.

**How to apply salt.** Just before the salt is applied, the milled curd is spread in an even layer over the bottom of the vat. It should be approximately the same depth in all parts of the vat to facilitate even distribution of salt. The curd should be free from lumps at this time. About one-third of the salt is sprinkled evenly over the curd and is stirred in before more salt is added. This procedure is repeated a second and a third time; after each portion of salt is added the curd is again stirred over completely. If the salt is applied too rapidly, it tends to harden the surfaces of the curd particles and is washed off by the whey which normally exudes from the curd during this salting operation.

After salt is applied to the curd, it will no longer tend to mat together as it did before salting. It can be piled high along the sides of the vat, or at the end of the vat, while the salt is dissolving and being absorbed. Stirring over the curd once or twice will help to keep the temperature uniform and will redistribute the salty whey which drains very slowly through the pile. McDowall and Dolby (1936) found that in 15 minutes the salt penetrated little more than 0.05 inches, and that in an hour and one-quarter it had only diffused 0.15 inches into the curd. Hoecker and Hammer (1944) found that it was fairly uniform throughout the curd particles 24 hours after pressing.

The curd can be placed in the hoops and pressed as soon as the salt is properly dissolved. If it is held for any considerable period of time after salting, care should be taken to keep the curd covered. It is stirred often enough to keep it from matting and to keep the temperature uniform. It is necessary to fork the curd only occasionally during this period; seaminess can sometimes be traced to excessive forking, especially in an overheated vat.

## HOOPING

The hooping operation moves the curd from the vat into the hoops, or forms, in which the curd is pressed into its final shape.

**Condition of curd at hooping.** Before the curd is placed in the hoops, the salt is completely dissolved; the curd feels mellow and silky, somewhat as it did before salting.

The temperature of the curd at hooping usually ranges between 85 and 90°F. Factors which influence the choice of temperature are: size of cheese, temperature of pressing room, conditions of the curd, and rate at which pressure is applied. Small styles, like Young Americans or Longhorns, are hooped at the higher temperatures; a cool room requires warmer curd; curd lacking in plasticity is hooped at the warmer temperatures;

slow application of pressure or light pressure is more effective with warmer curd. During the hot season of the year, it may be necessary to cool the curd before hooping; this is done by running cold water in the jacket of the vat while the salt is being applied. Provisions may be made to hold the curd in a cooler room under such conditions.

The effects of hooping and pressing at too high temperature are: excessive loss of fat; decreased yield; development of abnormal flavors; exaggeration of bacteriological defects, like gassy curds; mealy-bodied cheese; and greasy cheese. The greasy defect is evident in several ways: the curd is greasy to handle when it goes into and comes out of the hoops; the greasy curd does not knit together properly during pressing so that plugs of fresh cheese tend to break apart easily; the color of the finished cheese is seamy; bandages do not stick well, and the curd does not form a smooth, close rind. This last effect is very serious economically because such rinds tend to crack and check and later mold grows

TABLE 13:2. STANDARDS FOR COMMON STYLES OF CHEDDAR CHEESE AND CHEESE HOOPS

(Wisconsin State Department of Agriculture, 1941)

| | *Size of Hoop* | | *Weight of Cheese* | |
|---|---|---|---|---|
| *Style of cheese* | *Diameter* * | *Height* † | *Range* | *Maximum* |
| | inches | inches | pounds | pounds |
| Cheddar | 14.5 | 11.25 | 70-78 | 78 |
| Twins | 14.5 | 5.25 | 32-37 | 38 |
| Daisy | 13.5 | 4.25 | 20-22 | Less than 23 |
| Longhorn | 6.0 | 13.0 | —— | Four cheese, not over 53 |
| Young American | 7.0 | 7.0 | —— | Four cheese, not over 48 |
| Commodore, Junior Twins, etc. | 9.75 | 5.0 | 11-12 | Two cheese, not over 25 |
| Square prints | ** | ** | ** | ** |

* Diameter of hoop, which is also the largest diameter of a tapering cheese, is the inside diameter across the hoop immediately below the shoulder which supports the bandager.

† Height of hoop, which is also the approximate height of the cheese, is the distance from the bottom of the hoop to the shoulder which supports the bandager.

** Square prints are made in hoops measuring 14 inches by 11 inches by 3.25 inches, inside dimensions; these measurements are made at points just below the shoulder that supports the bandager. Dividers are supplied to permit the making of prints of smaller size. The square print weighs 20 pounds. When the dividers are used, the units formed have a combined weight of 20 pounds with unit weights of 2, 2.5, 4, 5, or 10 pounds. One pound units are rarely made by the divider system.

in the openings. Checked cheese is heavily penalized on the market.

The effects of hooping and pressing the cheese at temperatures which are too low are: open texture, imperfect rind formation, uneven color, and lack of whey drainage.

Cheese hoops, although originally cylindrical, are now available commercially in other shapes and many different sizes. Such variations in shapes and sizes explain the numerous styles of Cheddar cheese. Table 13:2 summarizes the dimensions of some of the more common styles. Regardless of the style of hoop, it should be easy to clean and to assemble. It should be easy to dress and should hold the bandage securely and smoothly in place while the hoop is being filled with curd. It should deliver the cheese easily after pressing.

**Dressing the hoop.** Cheese hoops are lined with cloth before the curd is given its final pressing. The cloth is necessary to form a closed rind or surface; if the cloth stays on the cheese after pressing it provides protection and support for the cheese surfaces. Large hoops, like cheddars, are lined with cloth before the curd is first placed in them. Small hoops, like rectangular hoops for square prints, are filled with curd and pressed for 30 to 60 minutes without cloth in the hoop. The curd in the small hoop knits together well enough so that it can be taken from the hoop as a unit, wrapped in cloth, and replaced in the hoop for the final pressing. The arrangement of the cloth in the hoop before pressing, the smoothing of cloth around the cheese before the pressing is complete, and the wrapping of the cheese units in cloth after they have been partially pressed, constitute a series of operations which are called **dressing.**

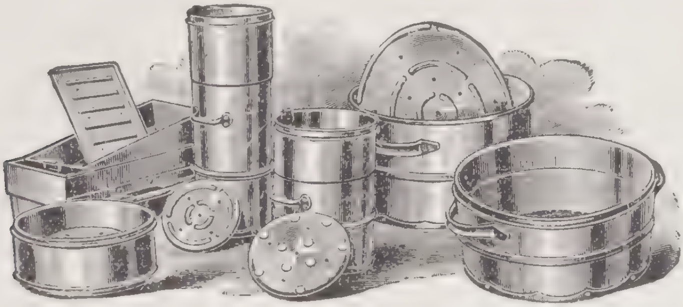


Figure 13:1. Several styles of cheese hoops. *(Courtesy of Oakes and Burger Company).*

The cloth used in dressing operations is of two kinds. A thin, loosely woven, cotton cloth, commonly known as cheesecloth, is used for bandages and starched circles; this cloth is used on cheese styles which are cured in these same cloths. A strong, unbleached muslin is used for covering the ends of cheese or for covering square prints of cheese during the pressing operations; this cloth is usually stripped from the cheese before it leaves the factory or before it is cured. This cloth is washed, sterilized, and reused in the factory; the thin cheesecloth used for bandages and starched circles remains on the cheese during ripening and is never reused.

The cheesecloth **bandage** is used to protect the sides of the larger styles of cheese; it overlaps about one inch on the ends of the cylindrical styles. When it is used on square prints, it is shaped to cover all surfaces without folding. The bandage is usually woven in tubular form to fit the common cylindrical hoops.

The cheesecloth **starched circle** is heavily sized cloth made in circular shape to cover the ends of the cylindrical styles of cheese.

**Cap cloths** are made of unbleached muslin. They are usually circular in shape and are the same diameter as starched circles. They are used to cover the ends of the cylindrical styles of cheese. They are commonly used over the starched circle. Starched circles are sometimes not used and then the cap cloth is used in direct contact with the curd. Cap cloths are stripped from the cheese before it is paraffined for curing. They are then washed, sterilized, and reused. They are essential for forming a smooth, solid surface on the cheese. They are sometimes called **press cloths.**

**Press cloths** are made of unbleached muslin. Although the name has long been used in the same sense as cap cloth, it is increasingly used to designate the cloth used to wrap square prints. They are used directly over the curd. They are shaped so that they cover all surfaces of the blocks without double or triple thicknesses. Press cloths are removed from the blocks just before paraffining or just before the blocks are covered with the special wrappers used in making packaged cheese. They are washed, sterilized, and reused.

Substitutes for press cloths have been used experimentally. The most successful type has been strong, heavy-bodied paper which approximates the wicking effect of the press cloth. This material is particularly useful when it is used in pressing of cheese for packaging. The paper substitute has not been perfected for general commercial use. If it can be perfected for factory use, it will simplify the sanitary and labor problems involved in cleaning and sterilizing the unbleached muslin press cloths and cap cloths.

**Method of dressing cylindrical hoops.** Hoops are carefully lined with the cloths in order to give the best possible appearance and smoothest surface to the finished cheese. In dressing cylindrical hoops, a moist cap cloth is first spread smoothly over the bottom. Over this is placed a dry starched circle. The bandage is then slipped over the outside of the rim or metal bandager which is used to suspend and hold the bandage smoothly and evenly around the sides of the hoop while it is being filled with curd. The rim, surrounded by the bandage, is then carefully pushed down into the top of the hoop until it rests on the shoulder on the inside of the hoop. If the bandage has been properly placed on the rim it will hang smoothly and evenly around the inside of the hoop and will overlap about 1 inch on the starched circle in the bottom. After the required number of hoops have been dressed in this manner they are ready to be filled with curd.

**Filling the hoops.** Clean cheese hoops can be placed directly in the vat bottom where they can be easily filled with curd. Large hoops, like cheddars, may be left in the press and filled there, in order to avoid the necessity of lifting the heavy hoops of curd out of the vat. Curd is weighed into the hoops accurately enough to form cheese of uniform size. This is essential when cheese is made in squares for packaging purposes. Extra curd is pressed in a small hoop. If the style of cheese permits some variation in finished weight, the extra curd may be distributed uniformly among the hoops that have been filled to a predetermined weight. Sometimes it is better practice to remove a small portion of curd from the previously filled hoops in order to make an additional cheese with the extra curd. It is not good practice to save a part of a hoop of curd from one day to mix into the next

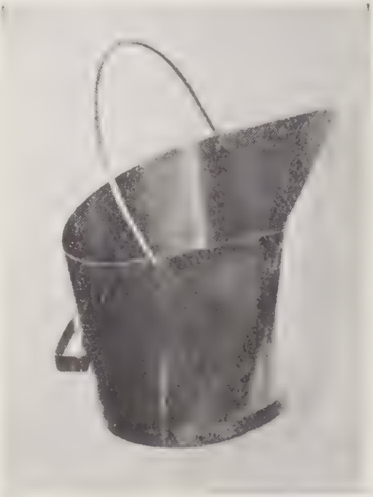


Figure 13:2. Curd pail. *(Courtesy of Damrow Bothers Company).*

day's curd; color defects are usually found in such combinations.

When the curd is all in the hoops, a wet cap cloth is laid over the leveled curd in each hoop, a follower, or cover, is placed on the cap cloth to close the hoop, and the hoops are then ready for the preliminary pressing. Sometimes it is advisable to let the curd settle in the hoops before they are turned on edge and telescoped for pressing.

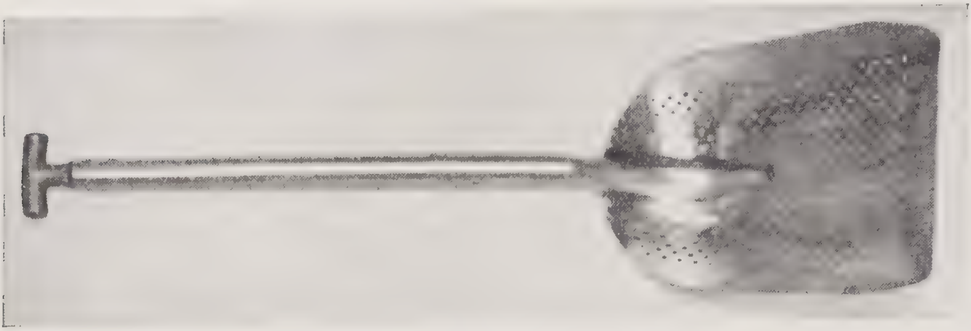


Figure 13:3. Curd shovel, strainer type. *(Courtesy of Damrow Brothers Company).*

## PRESSING

**Pressing** is the operation of forcing the particles of milled and salted curd in the hoops into the smallest possible space. Pressing takes place in two stages. The first stage is a preliminary pressing which shapes the cheese and reduces it almost to its final volume. The preliminary pressing stage ends after 30 to 60 minutes with the dressing of the cheese. The second stage begins after the cheese has been dressed and lasts from 6 to 20 hours; it is usually complete in 15 hours.

During pressing, the plastic curd particles slowly flow together. Air spaces and pockets of whey between the curd particles are expelled from the hoop when pressure is properly applied. The whey squeezed out of the hoops of curd during pressing comes principally from the surfaces rather than from the interior of the curd particles. Pressing alone does not make a close textured cheese; this can only be accomplished by maturing the curd during the cheddaring operation, and by establishing the proper conditions to permit the knitting together of the curd in the hoops.

**Applying pressure.** When the curd is put in the press in a normal condition, a moderate pressure causes the pieces to knit together in a smooth solid mass. The pressure is applied lightly and gradually at first; it must be applied rapidly enough to prevent settling of the curd in the bottom half of hoops as they lay in the press. Full pressure is reached in about 30 minutes. Too much pressure at first traps whey in the openings between the curd particles and tends to cause open texture. Excessive pressure at first may cause loss of curd around the followers. Too much pressure or too little pressure at first may cause lopsided cheese. After the curd has been pressed for 30 minutes, it is ready for dressing.

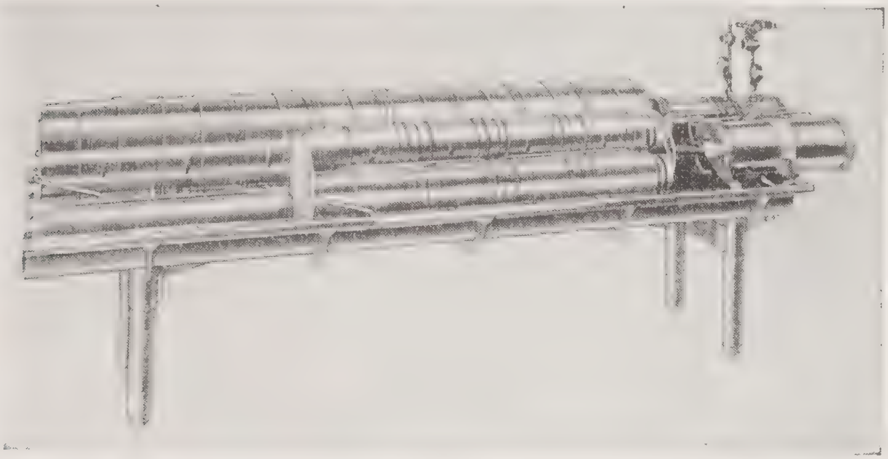


Figure 13:4. Hydraulic Cheese Press. *(Courtesy of Damrow Brothers Company).*

**Dressing the cheese.** The pressure is removed and the hoops are turned right side up in the press to dress the cheese. If they are allowed to remain on their sides in the pressing position, the warm curd may settle to the low side of the hoops and produce lopsided cheese.

The operation of dressing cylindrically shaped cheese arranges the bandage, starched circle, and cap cloth on the top of the cheese in the same way they are at the bottom of the hoop. First the follower, or cover, is removed from the hoop. Next the rim, or metal bandager, is slipped out of the hoop, leaving the upper edge of the bandage exposed. If the curd is above the level of the shoulder of the hoop then the rim is replaced immediately; if the curd is below the shoulder then the rims in some types of hoops are removed, washed and put away for the next day. The cap cloth is removed from the top of the cheese and the edge of the bandage is pulled up to remove all wrinkles which might have formed during the initial stages of pressing when the curd was being pushed together. The bandage must be smooth because any wrinkles remaining in it will cause cracks in the rind of the cheese. The edges of the bandage are then lapped over the top of the cheese, smoothed out as much as possible over the exposed curd, and are then wet down with an abundance of clean, hot water. The hot water makes the bandage stick and helps to form a good rind. The lap of the bandage approximates one inch. All loose threads are removed. A starched circle is placed over the top of the cheese and is sprinkled liberally with hot water wrung out of the cap cloth. The cap cloth is then spread smoothly over the starched circle and the follower is replaced.

The dressing of 20-pound squares and similar hoops of cheese is accomplished by turning the block of cheese out of the hoop onto the outspread bandage or press cloth. The bandage used for this style of cheese is starched cheesecloth; it is precut to fit the block of cheese to be wrapped. The press cloth is also precut to wrap the block completely with no folds that might cause uneven surfaces. When the bandage is used, the press cloth is also used in dressing the block; otherwise, the press cloth is used alone. When press cloths are used alone, some manufacturers have found it desirable to soak them in salt brine so they won't stick to the cheese and tear the fresh curd apart when they are finally removed from the block.

**Final pressing.** As soon as all hoops of cheese have been dressed, they are again turned down in the press and telescoped in the pressing position. Full pressure is applied at once. It is good practice to rinse the outside of the hoops with a pail or two of hot water, especially if the room is cold. The purpose of this is to warm the hoops slightly so that the surface of the cheese will be closed more quickly. It also rinses the hoops and the press and removes bits of curd and whey which might be attractive to insects or other pests. Maximum pressure, which in some modern, hydraulic presses totals 3200 pounds with 25 pounds of water pressure, is maintained for a period of approximately 15 hours.

**Taking cheese from hoops.** The cheese is taken from the hoops the day after making. This is done by loosening the cheese with a speed knife. This knife is a thin spatula with no cutting edge. It is inserted carefully between the cheese and the side of the hoop and is pulled around the hoop. Care must be taken not to cut the bandage in this operation. The hoop of cheese is then turned upside down on a clean surface. The cheese should drop out of the hoop readily. Some of the smaller styles, like Longhorns, may have to be dropped squarely on the surface from a height of a few inches to make them slip out of the long hoop. Cheddars and larger styles should be handled with care because pounding them out of the hoop tends to crack the surface and cause defective rind.

When the cheese is removed from the hoop, it should be neat, clean, uniform in size, and regular in shape. A lopsided, uneven or "hillside" cheese should be pressed again. Wrinkled bandage should be smoothed out, wet with hot water, and pressed on the cheese again. Open surfaces on the ends or sides of the cheese must be closed by washing the surface with hot water, arranging the bandage properly, and repressing the cheese until the openings have closed. Such defects in the finish of the cheese are unnecessary and, with careful handling and attention to details, they can be avoided. A badly finished cheese is a handicap which no careful maker will willingly accept. Imperfections in quality are often minimized when the finish and general appearance are attractive.

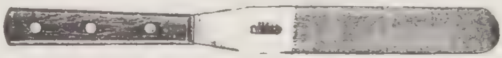


Figure 13:5. Speed knife for removing cheese from hoops. *(Courtesy of Oakes and Burger Company).*

## FACTORY CURING ROOM PRACTICE

Stamping cheese, as it is removed from the press, with date, state-assigned factory number, and variety name, is required in most states where cheese is made. In addition to these marks there may be others, such as: "Made from pasteurized milk," or the brand of the state in which the cheese is made, or the trade mark of the manufacturer. Such marks are commonly placed on the cheese soon after it comes from the press.

The cheese is moved from the making room to the drying room where it is neatly arranged on clean shelves or tables. The temperature is maintained at 55° to 60° F. with a relative humidity of approximately 50%. The cheese is turned at 24 hour intervals so that both ends and the sides of the cheese can dry and form the desired rind. Each time the cheese is turned, the shelf on which it stood and the surface in contact with the shelf are wiped with a clean dry cloth. Under such conditions the surface of the cheese will feel dry to the touch and show proper rind development in three or four days. As soon as these changes have occurred the cheese can be paraffined. In some states the minimum holding period from the press to the time of paraffining is fixed by regulation because of the necessity of having proper rind development to begin the long curing operation.

The control of mold in the factory drying room determines the amount of mold contamination on the cheese when it is paraffined. It is essential to keep the factory drying room in excellent condition. Shelves should be removable so that they can be taken quickly to a sink and thoroughly washed, sterilized, and dried. This should be done each time the cheese is moved from the shelves. New cheese should only be placed on clean shelves. The use of 10% formaldehyde solution to wipe mold off cheese and shelves is a disagreeable task that can be avoided by the frequent and proper use of a scrubbing brush and sterilizing solution.

## PARAFFINING CHEESE

When the surfaces of the cheese are properly dried, then the cheese is ready for paraffining. Paraffining is the operation of dipping the cheese for a few seconds into a bath of melted paraffin or a mixture of paraffin and waxes. This operation is completed in factories remote from central storages. In other areas the factories commonly box the cheese and truck it to the warehouse or storage where the paraffining is done by the buyer of the cheese.

**Purpose of paraffining.** Paraffining is an efficient method of decreasing loss of moisture from the surface of the cheese during curing. It prevents extensive growth of mold on the surface of the cheese, although it is not mold-proof. The paraffin coating is an excellent protection against insect infestations as long as it is free of cracks.

**Kinds of paraffin used.** The most common type of paraffin used is a product of the petroleum industry; it is known as **paraffin wax.** The type used for cheese has a melting point of 125° to 127° F. At ordinary temperatures used in curing storage this wax is hard and inclined to be brittle. At room temperature it is softer but still retains a degree of brittleness that is indicated by its tendency to crack if the paraffined cheese is distorted by pressure. Molds, and insect pests grow in such cracks in paraffin, and moisture losses are increased when they occur.

A second type of wax is being used for special purposes in the cheese industry; this is known as **microcrystalline wax.** It is produced by removing oil from petrolatum (Dean, 1945). It is tougher, and more flexible than paraffin, it somewhat resembles beeswax, and it is mixed with paraffin to impart some of these properties to the coating for cheese. The nature of this wax makes it highly resistant to water vapor, and it is flexible over a wide range of temperature; both of these properties are useful in protecting cheese. Combinations of paraffin and microcrystalline wax that are being used for coating cheese are usually sold under special names. They are commonly known in the cheese industry as flexible waxes. Flexible waxes are frequently colored; red, brown, and black have been widely used, principally for the identification of special brands.

**Preparing cheese for paraffining.** When cheese is ready to be paraffined, the press cloths are removed. Loose starched circles are completely removed. Dangling threads and loose edges of bandage are pulled or trimmed away. Any ridges on the end of the cheese are cut away so there are no rough areas to encourage growth of mold.

Samples of cheese for analysis are taken before the cheese is paraffined so that holes will be more completely protected by the wax coating. All grading of the cheese for primary market is usually done shortly before the cheese is paraffined for the same reason.

Permanent marks, brand names, or other necessary marks of identification are placed on the cheese at this time if they have not previously been applied.

**Paraffining the cheese.** The paraffin is melted by steam-heated coils in a steel tank. The paraffin tank holds enough paraffin so that, when it is melted, the cheese can be entirely submerged in it. Several cheese are usually dipped at one time. This is made possible by a metal rack with wooden slats on which the cheese rests while it is dipped. These racks or carriages are raised and lowered by hand in small units and by electric motors in the larger units. The temperature of the paraffin in the tank is maintained at 220° to 250°F.

The cheese is laid on the rack on its bandaged, curved surface. It is immersed completely and quickly, held for 5 seconds, and allowed to drain for 10 seconds, or until it can be handled without rubbing off the coating. The early work of Doane (1911) on paraffining cheese indicated that temperatures of 220°F. or higher should be used. He also found that the time of immersion could be varied from 1 to 10 seconds without material differences. These recommendations are still being observed in the industry.

Marks left by the paraffin rack should be brushed with hot paraffin to give a complete seal.

Overheating of paraffin wax causes oxidation and browning of the material. This is accompanied by the development of off odors. The defects are particularly apparent when small pieces of rind, threads from bandages, and grease from cheese, get into the paraffin. This oxidation process is accelerated by the presence of copper (Bennet, 1944).

Overheating of the cheese, by dipping at excessively high temperatures for long periods of time, causes softening of the rind or even melting of the rind. This causes deep dents in the surface of the cheese where it rests on the dipping rack. Murray (1928), however, recommended temperatures of 295° to 306°F. because then the wax becomes an integral part of the cheese. We have never observed temperatures used as high as Murray suggests.

If the temperature of paraffin is too low, then the paraffin wax adheres in a heavy layer to the cheese. It is easily cracked because it is so thick, and it soon breaks away from the cheese. Low temperatures probably do not have the same sterilizing effect on molds and surface organisms as the recommended temperatures of paraffining.

The temperature and duration of paraffining affect the amount of coating retained on the cheese. Doane (1911) found that 8 daisies dipped for 1 second at 190°F. retained 1.13 pounds of paraffin. The same number of daisies dipped for 1 second at 240° to 275°F. retained only 0.91 and 0.72 pounds of paraffin, respectively. When 8 daisies were dipped for 10 seconds at temperatures of 240° and 275°F. the group retained 0.65 and 0.50 pounds of paraffin.

## BOXING THE CHEESE

As each cheese is removed from the paraffining rack it is weighed and the weight is marked on the box in which it is to be placed. The box is then slipped over the cheese, the box and its contents are turned right side up and the cover is placed on the box. A thin, paper-like slice of wood, called a **scaleboard**, is usually placed under and over the cheese in the box to minimize sticking.

Boxes are made to fit cheese of uniform size and weight. If a cheese is so large the cover rests upon it, it is almost certain to be damaged in the curing process. It may damage other cheese by causing the stack in which it is piled to fall over when it goes out of shape under pressure. The boxes may be wired shut or fastened with nails if they are to be shipped. Such fasteners should not go through the box and into the cheese.

## MARKING BOXES

The boxed cheese is moved with hand truck from the paraffining and boxing room into the curing storage. Here each vat lot is piled together; each box is identified by a storage number; and each lot is marked with a suitable tag or card so that the warehouse operator will know its origin, weight, age, and quality. Such information is necessary for purposes of inspection, handling, and inventory during the period that the cheese is retained.

The cheese is now ready for curing or shipment for other purposes.

## REFERENCES

Bennet, H. (1944). Commercial Waxes. New York, N. Y., Chemical Publishing Co., p. 23.

Dean, John C. (1945). Chem. and Eng. News, *23,* 13:1164.

Doane, C. F. (1911). U. S. Dept. of Agr., Bur. An. Ind., Circ. 181.

Dolby, R. M. (1941). New Zealand J. Sci. Technol., *22A,* 289.

Hoecker, W. H. and Hammer, B. W. (1944). Food Res., *9,* 4:278.

Marquardt, J. C. and Resi, L. (1940). Nat. Butter and Cheese J., *31,* 10:32.

McDowall, F. H. and Dolby, R. M. (1936). J. Dairy Res., *7,* 156.

Murray, I. (1927). New Zealand J. Agr., *37,* 375.

Riddet, W., Valentine, G. M., McDowall, F. H., and Whelan, L. A., (1933). New Zealand Dept. Sci. Ind. Research, Bul. 37.

Spain, John F. (1942). Nat. Butter and Cheese J., *33,* 9:18.

Tuckey, S. L. and Ruehe, H. A. (1940). J. Dairy Sci., *23,* 517.

Wisconsin State Department of Agriculture (1941). Wisconsin grades and regulations for American cheese, cheese boxes, and cheese hoops as amended. June, 1941.

## CHAPTER 14

# MODIFICATIONS OF THE CHEDDAR PROCESS

It has seemed best to reserve a special chapter for descriptions of special modifications of the Cheddar process of manufacture. These modifications include: (1) the making of Cheddar cheese from pasteurized milk; (2) the making of cheese by the stirred-curd or granular, process; (3) the washed-curd, or soaked curd, process; and (4) the making of Colby cheese.

This chapter includes only the essential steps in these special modifications. The techniques employed in the handling of curd, and the adjustments of such factors as acidity and moisture content have already been described and discussed in principle in the chapters on Cheddar cheese.

### PASTEURIZED-MILK CHEDDAR

The use of pasteurized milk for Cheddar cheese makes it possible to follow a routine schedule from day to day. Sammis and Bruhn (1912) and Price (1927) commented on the uniformity of the making operations when pasteurized milk was used. Sammis and Bruhn suggested that the steps could be timed by clock; this may be the origin of today's catchwords of "making by the clock." Price outlined successful making operations showing the time schedule and acidity developments at critical points. He described curd characteristics and acidities to be attained at each step and indicated the actual variations which naturally occurred in factory practice.

Brown and Price (1934) and Spicer and Burgwald (1935), using electrometric measurements to supplement the usual factory tests, pointed out the relation between the acidity at each critical stage of the making operation and the acidity and quality of the ripening Cheddar cheese. They observed that cheese was most acid on the third or fourth day after making, and that pH values lower than 5.1 to 5.05 at that time were associated with acid defects. They reported that high acid values at setting, dip ping, and milling were directly associated with high acid in the cheese.

Wilson, Hall and Rogers (1945) emphasized that the rate at which acidity developed had a definite effect on the quality of the cheese made from pasteurized milk; the quality was damaged when lactose fermented so rapidly that maximum acidity was reached before the cheese was removed from the press. Their data on laboratory-made cheese indicated that pH values of 5.46 to 5.60 in the curd at milling gave the greatest proportion of high-scoring cheese. These results were confirmed by Walter and Lochry (1945) who showed factory data from 579 vats of pasteurized-milk Cheddar. They observed the highest proportions of U. S. No. 1 grade when the titratable acidity of the whey at milling, about four hours after adding rennet, ranged between 0.35 and 0.55 per cent. The average pH value corresponding to this range of titratable acidities approximated 5.42.

Price (1944) presented a systematic description of the making of Cheddar cheese on a timed basis; the following schedule is based upon that description.

## SCHEDULE FOR MAKING CHEDDAR CHEESE FROM PASTEURIZED MILK

In order to make this schedule as specific as possible, it will be assumed that 10,000 pounds of milk with 3.5 per cent fat is to be made into cheese containing 37 per cent moisture. A regenerative, high-temperature, short-time pasteurizer which has a capacity of 10,000 pounds per hour is used. Operations begin at 7:30 A.M. The complete typical making record is shown in table 14:1.

The success of keeping on a time schedule depends upon the milk, the condition of equipment and the quality of the starter. The raw milk should be clean in flavor and preferably have a methylene blue reduction time of not less than five hours. The pasteurized milk should be negative to the phosphatase test. The pasteurized milk should touch only clean, chlorinated, or otherwise sterilized, equipment. The starter must be of good quality; it must be active and dependable, if the proper acid development is to be attained at the right time.

A diagram of the pasteurizing unit and its essential milk control valves is shown in figure 14:1.

**7:30 A.M.—Sterilize equipment**

The pasteurizer and pipelines are set up ready for the day's work. Utensils like pails, knives, strainers and agitators are placed in the bottom of the cheese vat where they will eventually be covered with the chlorine solution. About 1000 pounds of 100 parts per million chlorine solution is placed in the raw-milk supply tank. This solution is pumped through the pasteurizer, filters, pipelines, and finally into the cheese vat. The chlorine

TABLE 14:1. SCHEDULE FOR MAKING CHEDDAR CHEESE FROM PASTEURIZED MILK. (PRICE, 1944)

| MILK | | STARTER | | CHEESE | |
|---|---|---|---|---|---|
| *Pounds* | 10,000 | *Pounds* | 70 | *Pounds* | 945 |
| *Meth. Blue, Raw* | 5 hrs. | *Age* | 15 hrs. at 7:30 | *Moisture* | 37% |
| *Flavor* | Clean | *Acidity* | 0.70% | *Fat* | 34% |
| *Milk fat* | 3.5% | *Activity* | O.K. | *Style* | *Daisy* |

Pasteurization treatment—160°F. for 20 seconds

| *Steps in Making* | *Time of each step* | *Minutes to next step* | *Temperature* | *Acid* | *Rennet Test* | *Comments* |
|---|---|---|---|---|---|---|
| Add starter | 8:15 | 30 | 86° | .16 | 3½ | Strained 70 lbs. |
| Add color | 8:45 | 15 | 87° | .16 | 3½ | 10 ounces |
| Add rennet | 9:00 | 12 | 88° | .165 | 3¼ | 30 ounces |
| Coagulation | 9:12 | 18 | 88° | No test | No test | Vat covered |
| Cut | 9:30 | 15 | 88° | .10 | *Hot Iron* | ¼″ knives |
| Steam on | 9:45 | 30 | 88° | .10 | No test | Slowly by schedule |
| Steam off | 10:15 | 45 | 102° | .105 | No test | Slow agitators |
| Settle curd | 11:00 | 30 | 102° | .12 | Trace | 8″ to 10″ deep |
| End dipping | 11:30 | 15 | 102° | .14 | 1/16″ | 18″ trench |
| Pack | 11:45 | Turn curd every 15 minutes | 101° | .17 | 1/16″ | Blocks 7″ wide |
| Pile two high | 12:30 | | 96° | .25 | ¼″ | Cut blocks in half |
| Pile three high | 1:00 | | 93° | .30 | ⅜″ | Smooth ends |
| Mill | 1:30 | | 91° | .40 | ½″ | Smooth, silky |
| Salt | 1:50 | 40 | 89° | No test | No test | 25 pounds |
| Hoop | 2:30 | 20 | 88° | ” | ” | All salt dissolved |
| Press | 2:50 | 30 | 88° | ” | ” | Full pressure in 15 min. |
| Dress | 3:20 | | | ” | ” | Well closed |

is drained from the equipment just before the milk begins to flow from the intake into the raw-milk supply tank.

### 8:00 A.M.—Pasteurize the milk

Start the pasteurizer by circulating water from the water supply tank through the regenerator, heater, holder, and cooler sections, and finally back to the water supply tank again. This circuit is shown in figure 14:1. When the pasteurizing temperature has been adjusted correctly for 5 minutes, then force the water out of the pasteurizing unit with incoming raw milk and run the pasteurized milk into the cheese vat.

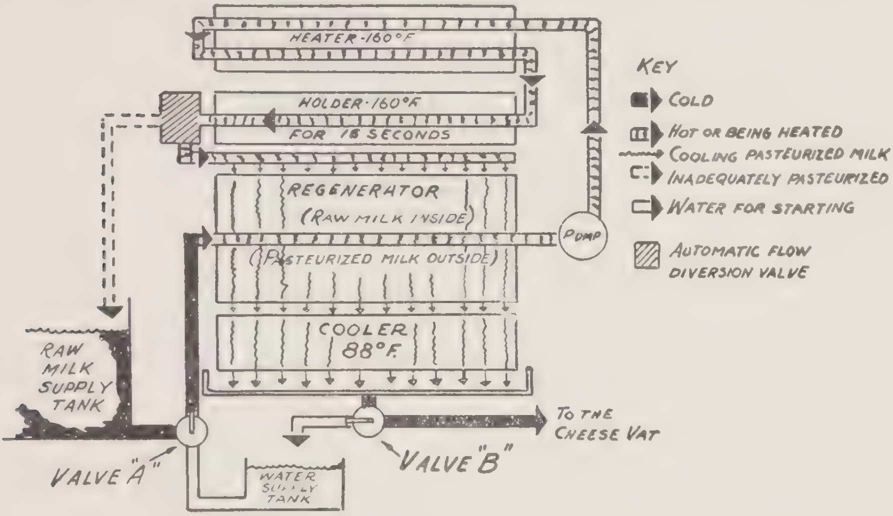

HEATER-160°F
HOLDER-160°F
FOR 16 SECONDS
REGENERATOR
(RAW MILK INSIDE)
(PASTEURIZED MILK OUTSIDE)
PUMP
COOLER
88°F.
RAW
MILK
SUPPLY
TANK
VALVE "A"
WATER
SUPPLY
TANK
VALVE "B"
TO THE
CHEESE VAT
KEY
COLD
HOT OR BEING HEATED
COOLING PASTEURIZED MILK
INADEQUATELY PASTEURIZED
WATER FOR STARTING
AUTOMATIC FLOW
DIVERSION VALVE

Figure 14:1. Regenerative, high temperature, short-time pasteurizer. This diagram shows one of several possible types of milk-to-milk regenerative systems. The pasteurizer is started with water circulating from the water supply tank, through the regenerator, heater, holder, and cooler sections, and finally back to the water supply tank again. When the pasteurizing temperature has been right for 5 minutes then valves "A" and "B" are turned to run milk from the milk supply tank through the pasteurizer and into the cheese vat.

### 8:15 A.M.—Add starter

The 10,000 pound vat is about one-quarter full of milk at approximately 88 F. Strain 70 pounds of starter into the milk; this is equivalent to 0.7 per cent. Mix the starter thoroughly with the milk. This is the first step in adjusting the rate of acid development. If the acid develops too fast or too slow then on succeeding days adjust it by following the instruction given on page 160.

### 8:45 A.M.—Adjust temperature

Adjust the temperature to 88° F. if it is necessary to do so. Measure out 30 ounces of rennet (three ounces per 1000 pounds) and dilute it with twenty times its volume of cold drinking water.

If color is to be used, measure it out, dilute it with cold drinking water and add it at this time before the rennet is added.

Make an acid test of the milk in the vat. It should test between 0.16 and 0.17 per cent. This represents a slight increase of 0.005 to 0.01 per cent over the acidity of the fresh milk. Variations in milk composition affect titration values; table 14:2 indicates what allowances should be made with low- and high-testing milks.

TABLE 14:2. RELATION OF MILK COMPOSITION TO TITRATABLE ACIDITY OF MILK AND WHEY

(Price, 1944)

| *Fat in milk* | *Acid in milk* | | *Acid in whey* | | | |
|---|---|---|---|---|---|---|
| | *Fresh* | *Setting* | *Cutting* | *Settling** | *Packing* | *Milling* |
| % | % | % | % | % | % | % |
| 3.0 | .15 | .155 | .10 | .12 | .16 | .40 |
| 3.5 | .16 | .165 | .11 | .13 | .17 | .41 |
| 4.0 | .17 | .175 | .12 | .14 | .18 | .42 |
| 4.5 | .18 | .185 | .13 | .15 | .19 | .43 |

* Settling is just before the whey is drawn.

### 9:00 A.M.—Add rennet

When the milk is all in the vat, speed up the agitators and, at exactly 9:00 A.M., add the rennet. The milk will thicken at 9:10 to 9:12 so all agitation of the milk should cease at 9:05.

### 9:30 A.M.—Cut the curd

Cut the curd into one-quarter inch cubes by cutting lengthwise of the vat with the horizontal knives and lengthwise and crosswise with the vertical knives.

Start the agitators on slow speed; increase the speed as it becomes necessary to prevent formation of lumps of curd.

Whey acidity at this time should be 0.10 to 0.11 for normal 3.5 per cent milk.

### 9:45 A.M.—Cook the curd

Turn on the heat slowly to raise the temperature at the rate of 1 degree in the first five minutes and 2° F. every five minutes for the next ten minutes so that it is 93° F. at 10:00. After that raise the temperature 3° F. every five minutes until the final temperature of 102°F. is reached at 10:15.

Continue to stir the curd slowly until 11:00—a total of 45 minutes after the cooking temperature reaches 102° F. At this time the curd will begin to feel "shotty" and firm.

### 11:00 A.M.—Settle the curd

Stop the agitators and remove them from the vat. At this time the whey should contain 0.12 to 0.13 per cent acid.

Push the curd back from the gate for a distance of 3 feet. Level off the curd under the whey with a rake. Start to draw off the whey at a rate to expose the bottom of the vat at the gate end by 11:30.

### 11:30 A.M.—Dip

While the whey is being drawn, push the curd from the center to the sides of the vat to make a trench lengthwise of the vat and 18 inches wide. The curd should be leveled at the sides of the vat and about 7 inches deep. Trim the exposed edges to make them square and smooth and scoop the loose trimmings back over the piles of curd at the sides of the vat. Cover the vat to keep the curd warm and clean.

### 11:45 A.M.—Pack

Cut the curd into blocks 7 inches wide and roll each block over so the vat side is up. Start rolling over the blocks at the gate end of the vat and leave enough space between them to permit whey drainage.

The acidity of the whey at this time should be 0.16 to 0.17 per cent—the same as the acidity of the milk at setting.

### 12:00 M.—Cheddar

Turn the blocks bottom side up. Turn them again at 12:15. Keep the vat covered.

### 12:30 P.M.—Pile two high

Turn the blocks over; place them close together and perpendicular to the sides of the vat. Cut each block in half, crosswise, and lift the half at the center of the vat and lay it on the half next to the side of the vat. Face the cut ends toward the center of the vat.

At 12:45 turn and repile the blocks, putting the bottom ones on the top.

### 1:00 P.M.—Pile three high

Turn the blocks and pile them three high. At 1:15 turn and repile the blocks, reversing them from bottom to top in the pile.

### 1:30 P.M.—Mill

The acidity of the whey should be 0.40 to 0.45 per cent. The temperature of the curd should be 90° to 93°F.

Mill the curd. Keep it stirred enough to prevent matting.

### 1:50 P.M.—Salt

Weigh out 2.5 pounds of salt for each 1000 pounds of the 3.5 per cent milk in the vat—this will total 25 pounds.

Spread the curd evenly over the bottom of the vat and sprinkle one-third of the salt uniformly over the curd and stir it in. Repeat this operation until the curd has been salted. Trench the curd and let it drain for ten minutes. Stir over the piles of curd and trench it again.

### 2:30 P.M.—Hoop, press and dress

The temperature of the curd at this time should be 87° to 89°F. The curd is now ready to hoop. Place the filled hoops in the press and apply pressure gradually until full pressure is on them after about 15 minutes. They can be dressed 15 minutes later. Full pressure should be applied overnight.

**Marking.** Cheddar cheese made from pasteurized milk should be identified by proper branding of the cheese itself. It is the only type of Cheddar under two months of age that can be sold in states like New York, Illinois, Indiana, California, and others; the labeling of the cheese is therefore more than an ordinary aid to orderly marketing. Identification of the factory, the state in which the cheese is made, the date of manufacture, and suitable grade marks will also usually be placed on this cheese in most cheese-making areas of the country.

**Curing.** This cheese is cured at temperatures ranging from 33° to 60°F. At the lower temperatures the development of flavor is slow and the cheese can be ripened for a year or more. At the higher temperatures the flavor develops more rapidly, is more pungent, and usually less uniform than that obtained at lower temperatures. At high temperatures of curing, cheese loses more moisture by evaporation, and is often damaged by mold growth and insect infestations. Curing at the higher temperatures must therefore be carefully controlled by close supervision. Extra labor is required in caring for cheese at the higher temperatures. Curing pasteurized-milk cheese at 40° to 45 F. and at a relative humidity of approximately 70 per cent produces a mild, pleasing, cheese flavor in four months. Losses by mold growth and insect infestations can be largely prevented under such conditions of temperature and humidity by careful sanitation and by inspection at monthly intervals to detect contamination.

## STIRRED-CURD OR GRANULAR PROCESS

**History.** The first cheese made in the farm homes of the early colonists in New England was made by the stirred-curd process. The modern practice of cheddaring, involving the matting, turning, and piling of the curd in slabs, replaced the stirred-curd process after the factory system of making became established in this country. Doane (1940) recalled that it was still commonly made in 1890. Many makers continued to make a portion of their cheese by the stirred-curd method because the process was slightly shorter and did not require the use of a curd mill. Some makers still use the process occasionally, so the method of making has not been forgotten in factory practice.

Cheese made by this process has, until recently, been available, chiefly at holiday seasons, in a special style known as Pineapple cheese. The style was so named because each cheese was pressed in a form which somewhat resembled that fruit in shape. The semblance was further enhanced by hanging the cheese for curing in small nets which imprinted on the curd a characteristic diagonal design like the leafy scales on pineapple.

**Modern trends.** It is possible that the amount of cheese made by the stirred-curd process will be increased. Marquardt (1943) called attention to the advantages the process offers of eliminating the curd mill and the milling operation, and shortening the time of making. Damrow (1947) perfected mechanical raking agitators and other equipment to eliminate the strenuous labor of stirring the curd by hand during the draining operation. With this equipment the draining of the curd takes about 30 minutes; salt is added 30 to 45 minutes later; and the whole process requires 3 to 4 hours from setting to hooping.

Pasteurization of milk was an unknown process in cheese factories 75 years ago when the stirred-curd process was used commonly. In modern operations this treatment eliminates the undesirable organisms in milk that can be controlled otherwise, and to a lesser extent, only by the cheddaring process. The characteristics of the cheese differ from those of the usual Cheddar in greater openness of texture and shortness of body. Such differences are of no moment when the cheese is used for manufacturing or cooking; they are insignificant, as a general rule, to the average consumer.

**Composition.** Cheese made by the stirred-curd, or granular, process is practically identical in composition to that made by the cheddaring process. Moisture normally approximates 37 per cent although it can easily be reduced to 34 per cent; it does not exceed 39 per cent. The amount of fat in the dry matter of the cheese is not less than 50 per cent. No formal standard of composition for this cheese has, as yet, been established. In years past it has been accepted as Cheddar and has conformed to the Cheddar standards. It is probable that the proposed definitions published by Food and Drug Administration (Federal Register, 1947) include the essential details of the standard which will eventually be adopted for the regulation of the product as it moves into interstate commerce.

**Characteristics.** The flavor of cheese made by the stirred-curd process is essentially the same as that which might be expected if cheese of the same composition were made by the cheddar process. The body of the cheese may be somewhat more curdy and less elastic when the cheese is fresh; low moisture cheese particularly shows this characteristic. The body of the cheese breaks down in curing at a rate that is comparable to that of Cheddar of similar composition and acidity. The texture of cheese made by this process is more open than that of normal Cheddar; the mechanical openings are much smaller and more numerous. The texture of this cheese reveals the essential difference in the manufacturing operation; the openings tend to occur where some of the curd particles failed to join during the pressing operation. A 10-fold magnification or microscopic examination of thin cross sections of this cheese shows outlines of round curd particles; the same magnifications of cheddared curd reveal curd particles in greatly elongated and flattened forms.

Cheese made by the stirred-curd and cheddar processes cannot be scored or graded alike because the openness of texture of the former is considered a defect in Cheddar cheese. Suitable allowances can be made in grading regulations, if it is desirable to do so, in order to allow for such normal differences. The color of the cheese made by this process is identical to that of Cheddar.

**Manufacture.** The making of cheese by the stirred-curd, or granular process begins with careful adjustment to the same rate of acid development which is used in making Cheddar. Temperatures of setting, amounts of color and rennet are identical to those used for Cheddar. Cutting of the curd is best accomplished with three-eighth inch curd knives unless a very dry cheese is to be made. The temperature of heating is one or two degrees lower than for Cheddar of the same moisture content.

**Draining and stirring.** The acid and firmness developed in the curd two and one-half hours after adding rennet are the same as for Cheddar: titratable acidity of the whey is 0.02 per cent greater than at cutting, the hot iron test shows one-sixteenth of an inch, and the pH is approximately 6.1; the curd is firm although a slightly lesser degree of elasticity is permissible because of the continuing firming action of the stirring which occurs during the draining of the curd. The removal of the whey is usually started two and one-half hours after adding rennet.

In the early days of cheese making in this country, curd sinks with draining cloths and racks were provided to facilitate the removal of the whey. The curd and whey were dipped out of the vats and poured onto the draining cloths of the curd sinks. In modern practice the curd is drained in the vat (Damrow, 1947). A retaining strainer is available which extends across the entire vat, and holds the curd away from the gate strainer; it forms a half-round, permeable, retaining wall behind which mechanical, raking and forking agitators keep the curd particles from matting together. Agitation at this time, whether accomplished by hand or machine, must be continuous enough to prevent the curd from matting into balls larger than one-half inch in diameter. During this time agitation must be stopped for about two minutes at intervals of five to ten minutes to permit practically all of the free whey to escape within a period of approximately 30 minutes. While the curd is warm it tends to mat together very easily. As the whey is removed and the surfaces of the particles become cooler, the curd tends to mat less readily. The stirring and draining of the curd can be simplified when the curd starts to "ball up" by adding 1 per cent of salt, based on the estimated weight of curd in the vat. This salt slightly hardens the surfaces of the curd particles so that they do not mat together and form balls of curd so readily; this hastens the draining of whey. The salt also has a slight shrinking action on the curd particles. This amount of salt does not delay acid development. Much of this salt is lost in the draining operations so that when the curd is finally salted before hooping, the total amount of salt should be decreased by approximately one-half pound for each 1000 pounds of milk used. The amount of salt incorporated in the cheese should be the same as in Cheddar.

When the curd can be trenched and piled at the sides of the vat to remove the last of the freely flowing whey, then the curd can be salted. At this time the acidity of the whey draining from the curd approximates 0.22 to 0.30%, the hot iron, one-quarter of an inch, and the pH, 5.8. Some makers prefer to delay salting until the acidity approximates that of Cheddar at salting.

**Salting and hooping.** Salt is applied at the rate commonly used for Cheddar. If large amounts of whey are draining from the curd, a suitable extra allowance must be made according to the judgment of the maker. Salt is added in two or three applications. After each application the salt is thoroughly mixed with the curd. After salting, the curd does not mat together readily, and lumps which may form are broken apart readily by stirring. The curd is then trenched, piled at the sides or end of the vat, and allowed to drain until it is hooped.

Between salting and hooping the curd is usually stirred over two or three times to promote uniform cooling and draining and to redistribute the salty moisture which accumulates at the bottom of the piles. As soon as the salt has dissolved and the whey has ceased to run freely from the curd, the curd can be placed in the hoops and pressed. This interval from salting to hooping is usually about 45 to 60 minutes. This curd can be pressed in any style of hoop used for Cheddar curd.

**Marking and curing.** Cheese made by the stirred-curd process has the food value and curing properties of normal Cheddar. Special marks, however, may be required to identify it for trading purposes. Other marks on the cheese, excepting grade identifications, unless otherwise specified, should conform to those used for regulatory purposes in marketing Cheddar cheese. Manufacturers of this type of cheese should consult state and federal regulatory agencies concerning the identification of this cheese in commerce until uncertainties concerning the standards and definitions (Federal Register, 1947) have been settled.

## Washed-curd Process

Cheese made by the washed-curd or soaked-curd process is required by federal definition (Federal Register, 1941) to have not more than 42 per cent moisture and not less than 50 per cent fat in the dry matter. In factory practice the moisture content approximates this limit. According to these standards the milk from which the cheese is made may be standardized by removing a portion of the fat or by adding skim milk or cream.

Soaked-curd is a term sometimes used to indicate the severity of the washing treatment. The distinction is so difficult to define that the terms soaked and washed are commonly used interchangeably.

**Characteristics.** Cheese made by the washed-curd process is a modified form of Cheddar cheese that is made by covering the freshly milled curd of normal Cheddar cheese with cold water for a period of 5 to 30 minutes. The curd is then drained, salted at the normal rate and pressed in daisy, flat, or print style hoops. This washing treatment increases the moisture in the curd, causes a slight increase in the volume of the curd, extracts a portion of the lactose and soluble milk salts, removes a portion of the whey, and produces a characteristic soft body and open texture in the finished cheese.

This cheese is mild in flavor because it is cured only a month or two at temperatures not above 50° F. Its keeping properties are inferior to those of Cheddar. When it is held too long, the flavor deteriorates in a manner that suggests the onset of putrefaction.

This type of cheese is best made from pasteurized milk. Its quality and keeping properties are much improved by this procedure.

**Factory technique.** Factory methods of making cheese by the washed-curd process were studied by Price and Hochstrasser (1929). Practices varied widely; in general, when compared with normal Cheddar, they tended to incorporate more whey, to develop higher acidity, and to shorten the making time. During the cheddaring operation, for example, the curd was first piled 12 to 14 inches high at the sides of the vat, then cut into slabs 12 inches wide, and piled high at each turning of the curd. After only about 40 minutes the curd was milled, covered with water at about 58°F. and drained after about 20 minutes. Judges who examined cheese made in this manner generally attributed defects in flavor, body, texture and color to the presence of excessive whey and acid.

**Effects of water treatments.** Dean (1900) found that washing curd with water at 90° to 110°F. caused a slight decrease in yield and a small gain in quality when the curd had defective flavor. He could see no difference in quality of cheese made from washed and unwashed curd when the original milk was of good quality.

Price and Hochstrasser (1929) studied the making of this type of cheese experimentally to determine the influence of the temperature of the wash water, the duration of the washing treatment, and the addition of lactose to the curd to replace that lost in the washing treatment. Three lots of curd averaging 35.5 per cent moisture were given different washing treatments. When the weight of the wash water equalled the weight of the curd, and the period of washing was 15 minutes, they observed gains in moisture of 1.6, 2.3, 3.1, and 3.4 per cent with wash waters at 100°, 75°, 60° and 45°F., respectively. In a second series of ten trials the curd used for washing averaged 35.1 per cent moisture. Rinsing this curd with one-quarter of its weight of water at 60°F. increased the moisture content of the cheese 1.12 per cent. When the curd was covered with its own weight of water at 60°F. and some held for 7 and the rest for 25 minutes, the gains in per cent moisture were 2.45 and 3.45, respectively.

The quality of the cheese made from curd covered for 15 minutes with water at different temperatures was best after the treatment at 100°F.; the quality was worst after the 45°F. treatment; all of the cheese made from washed curd was inferior in quality to that made from normal curd. The deterioration was apparent chiefly in flavor although the body of the cheese was criticized for weakness. The quality of the cheese made from curd treated with water at 60°F. for different periods of time showed that extended washing treatments caused deterioration in flavor of the cured cheese. Rinsing the curd improved it slightly in body.

**Influence of adding lactose.** Babcock, Russell and Vivian (1901) observed that the addition of lactose to thoroughly washed curd tended to restore, in part, the quality of the original curd. This was later confirmed by Hastings, Evans and Hart (1912). These workers attributed the inferior quality of the cheese made from washed curd to the removal of lactose. They showed that the acid produced by the fermentation of lactose was essential for the normal ripening of Cheddar cheese. Price and Hochstrasser (1929) restored to washed-curd the approximate amount of lactose removed by the water treatment and observed that it produced firmer body in the young cheese and a slight improvement in the flavor of the cured cheese. They did not recommend the use of lactose in making cheese from washed curd.

Soluble calcium salts, as well as lactose, are removed from the curd during the washing treatment. Both changes in the composition of the curd alter the trend of the curing changes. Washed-curd cheese should not be held for more than the minimum time required for the development of acceptable body and flavor.

**Marking.** Washed-curd cheese satisfies the demands of certain consumers better than normal Cheddar cheese. It is best when made without the incorporation of excessive amounts of water. It is a different type of cheese than normal Cheddar and must be so identified for the information of the consumer and regulatory officials. The principal cheese-making states have regulations concerning the marking of cheese made by the washed-curd process to distinguish it from normal Cheddar. Other marks on the cheese, excepting grade identification, are usually identical to those used for Cheddar cheese.

## COLBY CHEESE

By federal definition (Federal Register, 1941), Colby cheese is required to have not more than 40% moisture and not less than 50% fat in the dry matter. The cheese normally closely approaches this limit of moisture content. According to these standards, the milk from which the cheese is made may be standardized by the removal of a portion of fat from the milk or by the addition of cream or skim milk.

**Characteristics.** Colby cheese is a popular modification of the Cheddar type of cheese. It is best when made from pasteurized milk. It is commonly made in Wisconsin, Illinois, Indiana, and Ohio and to a lesser extent in other cheese-producing areas. It is distributed to markets where soft-bodied, open-textured cheese with a mild, Cheddar-like flavor is preferred.

**Washing the curd.** In making Colby cheese, the procedures used for normal Cheddar cheese are followed until the time of dipping. It is advisable to use three-eighths inch knives at cutting in order to produce the desired characteristic openness of texture. The normal firmness and acid development are attained as usual. The whey is drawn down to the level of the curd as it rests without agitation at the bottom of the vat. The vat gate is then shut and cool drinking water is added to the curd and whey remaining in the vat. The temperature of this water varies in practice but 60° F. is satisfactory. The temperature of the water determines how much is added to the vat contents; less water is needed when it is colder than 60°F. and more is needed when the temperature is higher. Enough water has been added when the temperature of the mixture of curd, whey and water approximates 80°F. Temperatures below 80°F. produce cheese with more moisture; at higher temperatures, less moisture is incorporated in the cheese.

**Draining.** While the water is being added to the curd the mixture is stirred to obtain uniform temperature. This stirring is continued gently for 10 to 20 minutes after which the curd particles are pushed to the sides of the vat and the whey and water mixture is completely removed. The curd drains readily without matting at temperatures of 80°F. If higher temperatures are used, the curd particles will show a greater tendency to mat together. Under such conditions it may be necessary to fork the curd and repile it at the sides of the vat before the curd is ready for salting.

**Salting.** Salt is added approximately 60 minutes after the whey is drained from the vat. During this interval before salting there is a slight development of acidity. This change cannot be measured accurately by titration of the whey and water draining from the curd at this time although increases in acidity are indicative of the changes in the curd. The hot iron test cannot be used to measure this developed acidity because the particles of curd do not readily form a ball when squeezed together, as they did before the curd was treated with the cold water. Measurements of pH of the curd usually approximate 5.6. It is considered good practice to extend this period before salting to two hours in order to obtain a curd which will break down faster in curing.

Salt is added at the rate of 2% of the weight of the curd. It is added in two or three applications, as in the making of Cheddar cheese, and is stirred in thoroughly after each application. The curd is then piled at the sides of the vat and allowed to drain. It may be stirred over once or twice to obtain more uniform distribution of salt.

**Hooping.** The curd is ready for hooping when the salt is thoroughly dissolved. This will usually require a minimum of 20 minutes. The hooping of the curd can be delayed advantageously when it is desirable to decrease the amount of free whey expressed from the curd during the pressing operation. The usual styles of hoops used for Colby cheese are daisies, flats, and prints or squares. This cheese is rarely seen in styles which might lose shape readily while standing on a shelf. The cheese can be made, however, to suit any condition of storage.

**Defects in Colby cheese.** The most common defects in Colby cheese are probably sour and fermented flavors, woody, or tough body, and two-colored or mottled cheese. Sour flavor occurs when there is too much acid development in the vat before dipping, or when there is too little firming of the curd before washing, or both. Fermented flavor is commonly caused by inactive starter, by lack of acid development before and after dipping, or by the incorporation of too much moisture through the use of excessively cold water and low temperatures at the time of dipping. Woody, corky or tough body may be caused by lack of acid development and low moisture content; these conditions are usually induced by inactive starter, washing of the curd with excessive amounts of water, high temperatures of cooking, and by the addition of salt too soon after the removal of the whey and water mixture. Two-colored or mottled cheese may be caused by lack of acid development in the making process, by salting too soon, thus delaying acid development after dipping, and by draining the curd for too short a time either before salting or before pressing.

**Keeping properties.** The application of water in the making of Colby cheese increases the moisture content of the curd, and decreases the lactose and soluble salts. These changes tend to shorten the life of this type of cheese as compared to the normal Cheddar. Colby cheese made with a minimum water treatment closely resembles Cheddar cheese in keeping properties, but Colby cheese commonly made to suit the market demands for fresh, short-cure cheese should be moved into trade channels within approximately 12 weeks, and should not be subjected to unfavorable storage conditions if its quality is to be maintained.

**Marking Colby cheese.** The principal cheese making states have regulations that require the branding of Colby cheese to indicate its identity. This helps to distinguish it from normal Cheddar cheese with which it might be confused by the consumer. This identification is also helpful in regulatory supervision of trade practices. Other markings on the cheese correspond to those required for Cheddar.

## References

Babcock, S. M., Russell, H. L., Vivian, A., and Hastings, E. G. (1901). 18th Ann. Report, Wis. Agr. Expt. Sta., p. 162.

Brown, L. W. and Price, W. V. (1934). J. Dairy Sci., *17,* 33.

Damrow, E. C. (1947). Nat. Butter and Cheese J., *38,* 4:44.

Dean, H. H. (1900). Ont. Agr. College and Expt. Farm Report, 1900. p. 37.

Doane, C. F. (1940). Nat. Butter and Cheese J., *31,* 1:9.

Federal Register (1941). Federal Register, *6,* 6:195. Ibid. (1947). *12,* 37:1192.

Hastings, E. G., Evans, A. C., and Hart, E. B. (1912). U.S.D.A., Bur. An. Ind., Bul. 150.

Marquardt, J. C. (1943). Food Indus., *15,* 5:69.

Price, W. V. (1927). N. Y. (Cornell) State Agr. Expt. Sta., Memoir 105.

Price, W. V. (1944). Nat. Butter and Cheese J., *35,* 32:11.

Price, W. V. and Hochstrasser, W. (1929). Butter and Cheese J., *20,* 39:10. Sept. 25.

Sammis, J. L. and Bruhn, A. T. (1912). Wis. Agr. Expt. Sta., Res. Bul. 27.

Spicer, D. W. and Burgwald, L. H. (1935). Nat. Butter and Cheese J., *26,* 21:14.

Walter, H. E. and Lochry, H. R. (1945). J. Dairy Sci., *28,* 597.

Wilson, H. L., Hall, S. A. and Rogers, L. A. (1945). J. Dairy Sci., *28,* 187.

## CHAPTER 15

# DEFECTS IN CHEDDAR CHEESE: MOISTURE, ACIDITY, AND FLAVOR

Cheddar cheese, like all other varieties, has faults which occur again and again in factory practice. These faults are commonly recognized by discriminating consumers and judges of the cheese. These defects may be abnormalities in flavor, body, texture, color, or appearance of the cheese. Some of the more common of these defects will be considered in this discussion.

### Defects and Consumer Preferences

It is a well known fact in the cheese industry that characteristics of cheese that are desired in some markets are regarded as defects in other markets. Buyers of cheese in the primary markets know these preferences and distribute their supplies accordingly. A few examples of these preferences should be mentioned.

In some markets a cheese with low moisture is ideal; in such markets cheese with normal or high amounts of moisture is considered to be defective. People in some areas seem to prefer cheese with open texture, that is, with many mechanical openings. Critical judges of Cheddar cheese, however, designate openness of texture as a defect in grading and scoring cheese. The normal variations in the characteristics of wholesome Cheddar cheese may actually be regarded as an asset rather than a liability when careful marketing practices are followed.

The information in this discussion is intended to help the manufacturer control the quality characteristics of his product and to eliminate some of the more common defects which are condemned in all markets.

### Moisture Content

The presence of either too little or too much moisture in cheese is associated with certain characteristics. The qualities of the cheese affected are: flavor, body or consistency, texture or openness, and color. When moisture is extremely high or low, the finish of the cheese is also affected.

Moisture has an influence on all of these characteristics because it is directly related to the composition and physical qualities of the cheese. Moisture is indirectly related to these characteristics because it carries lactose and some of the milk salts in solution. Microorganisms change lactose into acids, chiefly lactic. A certain amount of such acid formation is necessary for proper cheese making and ripening; excessive amounts make the cheese taste sour; inadequate amounts may delay ripening or may actually encourage abnormal fermentations of undesirable organisms. The amount of moisture in cheese must be properly controlled.

**Excessive moisture.** The characteristics of cheese with excessive moisture depend upon the degree of the defect; they may be one or more of the following:

*Flavor* may be sour or acid or merely slightly acid when fresh, and lacking in cheese flavor and sour when aged. If the lactose was removed by excessive washing of the curd during making, then the flavor may be mild or lacking cheese flavor when fresh, and unnatural and offensive when cured.

*Body* is weak or soft when fresh, and sticky and pasty when aged.

*Texture* may be open; this usually happens if the acid development during the making operation was inadequate.

*Color* is frequently lighter than cheese of normal composition; it is usually bleached or "acid-cut" when acid characteristics dominate in the cheese.

*Finish* usually reveals weakness of body because the cheese tends to settle out of shape as it rests on the shelf or in the box. The cheese may leak whey for a few days after making.

**Causes of excessive moisture.** There are several possible reasons for this condition; one or more of them may be responsible for the characteristics which have been mentioned. These reasons are: An unusually high fat content in the milk that delays firming; lack of acid development during making; insufficient heating or heating too rapidly; incomplete removal or elimination of whey; incorporation of water by washing or soaking the curd.

**Preventions and remedies for excessive moisture.** It is usually not necessary to apply all the measures of control indicated; the results might produce cheese with too little moisture.

The corrections necessary can frequently be discovered by comparing the manufacturing records of the faulty product with the procedures which have been described in Chapters 11, 12, and 13.

*The milk* can best be standardized if it contains over 4.5 per cent of fat. This will simplify the firming operations, and will increase the efficiency of fat utilization.

*At setting*—use a faster rate of acid development by using more starter and ripening the milk longer. Add more rennet. Cut the curd early or while it is still slightly softer than the ideal. Cut the curd into smaller cubes; if smaller knives are not available, then recut the curd with the vertical knives.

*At heating*—raise the temperature more slowly and heat to a higher temperature. Do not exceed 104°F. if lack of acid development has been observed; higher temperatures tend to delay the action of the starter organisms.

*At dipping*—develop the maximum acid which will still permit the manufacture of sweet cheese. Stir the curd vigorously when the whey reaches the level of the settled curd; excessive stirring at this time may interfere with the matting of the curd. Remove the last of the whey promptly and do not allow any of the curd to remain in whey which may accumulate in the low end of the vat. Keep the curd in thin layers before packing; the depth may be as little as 4 inches, if there is space enough in the vat to spread out the curd. Cut the layers into small blocks at packing; the blocks may be as small as building bricks if necessary. Turn the blocks often and do not pile them during the cheddaring operation.

*At milling*—keep the curd warm. Delay the milling operation if the acidity is low; mill early if the acid is fully developed. Delay salting in order to give the milled curd every opportunity to drain. Salt heavily to increase the drainage and to add to the dry matter content of the cheese. Extra salt has a hardening effect on the body of cheese and delays ripening.

*After pressing*—develop a firm rind by holding the cheese in a dry room before paraffining. Hold the cheese in a cool, dry room during curing, and merchandise it promptly.

**Effects of insufficient moisture.** The effects of insufficient moisture in Cheddar cheese may be apparent in the following characteristics of the cheese:

*Flavor* may be mild and lacking; it may be slightly acid, if lack of moisture was caused by excessive acid development during making. Cheese flavor develops slowly.

*Body* is firm, hard, or corky, and sometimes crumbly and mealy. Loss of curdy characteristics during ripening is extremely slow.

*Texture* is usually close and solid but may show mechanical openness where curd particles failed to knit together properly during pressing.

*Color* is sometimes deeper in shade and rind formation is frequently distinctly darker in color than the rest of the cheese.

*Finish* may show defective knitting together of curd particles.

**Causes of insufficient moisture.** This condition may be caused by one or more of the following factors: maximum acid development throughout the making process; the use of excessive amounts of rennet or calcium chloride; fine cutting or breaking of the curd; heating and holding temperatures high; excessive stirring of the curd while the whey is being removed and immediately after dipping; lack of piling during the cheddaring operation; addition of too much salt; holding the cheese in a warm drying room too long before paraffining.

**Preventions and remedies for insufficient moisture.** It is usually not necessary to apply all the control measures suggested here to correct the faults of insufficient moisture. In factory practice the undesirable condition develops gradually and consequently corrective measures should be applied gradually as the need of them becomes apparent.

*At setting*—steps may be taken to reduce the acid development: reduce the ripening period, decrease the amount of starter added, add the rennet sooner. Reduce the amount of rennet. Do not use calcium chloride. Develop a firm curd at cutting and use coarser knives for cutting the curd.

*At heating*—the temperature may be decreased; if the temperature used approximates 98°F., then acid development may be stimulated.

*At dipping*—develop the minimum amount of acid recommended for a normal making procedure. Settle the curd 30 minutes before dipping and do not stir it at any time thereafter. As the curd settles under the whey, push it toward the sides of the vat to form layers approximately 10 inches deep. Remove the whey early and before the curd develops extreme firmness: this measure of control is the most commonly used and is entirely adequate even when applied alone in ordinary making practice. Cut the layers of curd into blocks 10 inches wide and pile them sooner than usual; pile them four or five high before it is time to mill. Allow the curd to cool during cheddaring.

*At milling*—use the minimum acid development consistent with recommended making procedures. Cool the curd promptly after milling by stirring and rinsing lightly with water at 60 to 70 F. Salt the curd promptly and use the minimum amount indicated for the composition of the curd in table 13:1.

*After pressing*—remove the cheese to a cool room and paraffin it as soon as the rind is properly dried.

## ACID CONTENT

The presence of too much or too little acidity in Cheddar cheese is associated with certain defects. Excessive acidity is found in cheese that contains more than normal amounts of moisture because such cheese contains more than normal amounts of lactose. Excessive acid development during the making process can also produce acid defects in the finished cheese even when the moisture content of the product is normal or perhaps less than normal. Acidity values observed by Brown and Price (1934) in making and curing Cheddar cheese of good quality are shown in table 15:1.

**Effects of excessive acidity.** All of the physical characteristics of Cheddar cheese may be affected by excessive acidity:

*Flavor* is acid or sour. Bitterness is sometimes associated with

TABLE 15:1. THE AVERAGE pH VALUES OF TITRATABLE ACIDITIES OF 14 LOTS OF CHEDDAR CHEESE OF GOOD QUALITY
(Brown and Price, 1934)

| *Time of observation* | *pH* | *Percentage of acidity* |
|---|---|---|
| Milk receiving | 6.56* | 0.166* |
| Rennet added | 6.47* | 0.185* |
| Cutting | 6.51 | 0.122 |
| Heat on | 6.43 | 0.124 |
| Heat off | 6.35 | 0.131 |
| Whey removed | 6.12 | 0.151 |
| Curd packed | 5.97 | 0.201 |
| Curd milled | 5.29** | 0.556 |
| Curd pressed | 5.25** | No whey |
| 1 day | 5.12** | 0.70*** |
| 3 days | 5.05** | 0.82*** |
| 7 days | 5.06** | 0.87*** |
| 49 days | 5.13** | 1.05*** |
| 9 months | 5.32** | ....... |
| 24 months | 5.58** | 1.19*** |

* = measurements made on milk
** = measurements made on curd or cheese
*** = measurements made by extracting cheese with water
All other measurements made on whey

too much acid development during making (Price, 1936, and Phillips, 1935). True cheese flavor is lacking or slow in developing.

*Body* may be firm, dry, crumbly, short, mealy, and sandy when the moisture content is low; it may be soft, pasty, sticky, short, and mealy when the moisture content is high.

*Texture* is usually close although in extreme instances the curd particles may be so poorly knitted together that numerous mechanical openings will be formed.

*Color* is bleached or acid-cut and sometimes mottled.

*Finish* may show uneven color or bleached areas. If the cheese also contains excessive moisture, it may leak whey for a few days after making. The rind may be checked or cracked.

*pH* is usually less than 5.05 when the cheese is 3 or 4 days old. As the cheese ages the pH gradually rises.

**Causes of excessive acidity.** Excessive acidity may be caused by the presence of too much moisture in the cheese; the reasons for this condition have been listed in the discussion of excessive moisture. Excessive acidity may also develop during the making operations and may be caused by any one, or a combination, of the following factors: the acceptance of high-acid milk from patrons; use of too much starter; prolonged ripening period; too much acid development before adding rennet; production of too much acid before the curd is firmed; dipping the curd too late; too rapid acid development before milling; and the presence of too much acid at milling for the moisture content of the curd.

**Preventions and remedies for excessive acidity.** When the characteristics and composition of the cheese indicate that the excessive acidity is caused by too much moisture in the cheese, then the preventions and remedies suggested for excess moisture can be applied. When the excessive acidity is caused by lack of acid control during the manufacturing operations, then one or more of the following measures may be applied:

*At the intake*—inspect the incoming milk carefully to eliminate that with acid development. It should be remembered that fresh milk, without acid development, may be either "high" or "low" in titratable acidity. If the acidity cannot be detected at the intake by odor or by titration, then the methylene blue test should be used daily on the milk delivered by each patron until on subsequent days all milk reducing in less than 4 hours has been eliminated.

*At setting*—decrease the amount of starter and shorten the time between the addition of starter and the adding of the rennet. Add the rennet when the first trace of acid development in the ripening milk can be detected by titration or by rennet test. Rennet must be added soon enough so that the curd can be properly firmed for dipping before excessive acid development occurs; the limit of acid development between cutting and dipping approximates 0.01%; maximum acid on the hot iron is one-eighth of an inch; maximum acidity in pH units approximates 6.0. Cut the curd before it reaches the optimum firmness for normal cheese, and cut it into smaller cubes. It may be necessary to recut the curd with the vertical knives.

*At heating*—apply the heat slowly as soon as there is enough free whey to float the curd. Heat the curd to a temperature of 104°F. If the acid seems to be developing at an uncontrollable rate it can be stopped until after dipping by heating to 112°F.; curd heated in this way must be dipped sooner than usual in order to avoid corky body.

If it is apparent after heating that the curd will not be firm before the acid development reaches its maximum, then an extreme remedy should be applied: firm the curd in warm water. Draw off the whey until the curd is just about to be exposed. Add warm water at the same temperature as the curd, approximately 104°F. The amount of water should equal the volume of whey removed. Finish the firming of the curd in the water and proceed with the making operations. The water treatment removes the lactose from the curd; this may cause flavors in the finished cheese like those that are found in cheese made by the washed-curd process.

*At dipping*—stir the curd vigorously as the whey is removed so that it will be properly firmed when the last of the whey is removed. Remember that excessive stirring of the curd after the whey has been removed will delay the matting of the curd. Keep the curd in thin layers before packing; a depth of 4 inches is not too thin. Cut the layers into small blocks at packing; they may well be 5 inches wide by 8 inches long. Turn the blocks often and do not pile them during the cheddaring operation. Let the curd cool at a normal rate.

*At milling*—take the normal acid development as the indication of the time of milling. Drain the milled curd thoroughly to permit the escape of whey. Rinse the curd with water at 60° to 70° F. using approximately 25 pounds of water for 100 pounds of curd. Salt the curd heavily, using the maximum amounts indicated in table 13:1.

*After pressing*—inspect the surfaces of the cheese for checks and cracks; if they are present, rinse the surfaces of the cheese with water at 140°F. and repress again as long as necessary to close the cheese.

**Effects of lack of acidity.** The common characteristics of Cheddar cheese with insufficient acidity are:

*Flavor* is mild when fresh, and fermented, fruity or lacking when aged. True cheese flavor develops slowly, if at all.

*Body* may be corky, pasty, sticky, or weak. The cheese remains curdy for a long time in curing.

*Texture* may be open, with large mechanical holes. The cheese may show large, round holes with shiny walls, called "sweet holes." Cheese with insufficient acidity may also show the effects of uncontrolled fermentations of gas-producing yeasts or bacteria. Such defects however can be partly ascribed to inferior milk rather than entirely to lack of acid.

*Color* may be wavy or mottled.

*Finish* may be uneven or out of shape if the cheese contains excessive moisture; it may also be slightly swelled by development of carbon dioxide or by gas from undesirable organisms.

*pH* is usually more than 5.3 when the cheese is approximately 4 days old.

**Causes of lack of acidity.** Lack of acidity is most commonly caused by failure of the starter to develop acidity during making; such failure may be caused by: inactive starter, unwise use of starter, unfavorable conditions for starter activity, or bacteriophage. It is possible that the presence of unusually large amounts of milk from abnormal or inflamed udders may cause delayed acid development, according to the findings of several investigators, among them: Whitehead and Cox (1933), Price and Roundy (1934), Davis and McClemont (1939), and Prouty (1940). Lack of acidity may also be caused by the use of unwise or undesirable manufacturing methods which firm the curd too much before normal amounts of acid have had the chance to develop. An example of such an effect would be the results of adding unnecessary amounts of calcium chloride in the milk.

**Preventions and remedies for lack of acid.** The efforts to correct this condition must begin at the intake and continue through the making operations. Particular emphasis and attention must be directed to the factors affecting the growth of the starter organisms.

*At the milk intake*—inspect the incoming product carefully for abnormalities.

*At setting*—add more starter and ripen the milk at the setting temperature until acid development can be measured by titration and by acid test. An increase of 0.01 per cent in titratable acid in the last 30 minutes of ripening and a change of one-quarter space on the rennet test in the last 20 minutes of ripening indicates adequate activity of starter at this time. Use three-eighths inch knives for cutting the curd.

*At heating*—use a lower temperature to encourage acid development and to retain more moisture; 96° to 98°F. can be used for the curd from milk with 3.5 per cent fat. Use minimum agitation in the handling of the curd.

*At dipping*—delay dipping until the curd is firm; holding the curd in the whey tends to increase the acidity of the finished cheese. Settle the curd earlier than usual; make the layers of curd at the sides of the vat deeper to retain the whey. Keep the curd warm after dipping by covering the vat at all times and by placing pails of steaming, hot water in the gate end of the vat. A little steam may be turned into the vat or into the jacket of the vat but the temperature of the vat surfaces should not be permitted to get above 100°F. Pile the curd to control the moisture; some of the treatments suggested may have retained so much moisture in the curd that there may be danger of an excess. Such cheese might lack acid at first but within a day or two after making the lactose would be converted into lactic acid and the cheese would become sour.

*At milling*—if the acid is still too low, hold the curd in the pack for an extended period. During this time the curd should be kept warm by high piling, frequent turning, and occasional warming of the vat with short jets of steam. Delay milling until the whey draining from the curd shows at least 0.30 per cent acid. The hot iron test should be nearly three-eighths inches long and the pH of the curd should be not more than 5.6.

If the acidity of the whey two hours after dipping does not exceed 0.25 per cent, then it is highly probable that the starter is faulty, or that it is contaminated with bacteriophage. Babel (1946) observed that prolonging the cheddaring operation for 4 or 5 hours did not help acid development when the phage was present. Holding the curd in the pack for 12 hours or longer sometimes permits acid development in curd affected with phage. The curd must be kept at approximately 85°F. during this period. Frequent turning to maintain uniformity in the blocks of curd is desirable. At the time of milling, this curd is usually so firm that smaller blocks than usual must be fed into the mill. Washing with warm water after milling, and salting lightly, seem to give the best results. This is purely an emergency treatment to be applied when acid development is extremely slow or practically non-existent.

When phage is the cause of lack of acid development, preventive measures are necessary. Clean the plant thoroughly; sterilize all equipment, utensils, pumps, and pipelines with strong chlorine solution just before using them; change the starter and get it from a different source. Follow the suggestions in Chapter 9 for controlling bacteriophage.

## Defective Flavors

Some of the more common defects in flavor are mentioned in alphabetical order in the following paragraphs. When it is possible to do so, common causes, preventions, and remedies are listed with each defect.

**Acid flavor.** This is the flavor of sour cheese. For its causes, preventions and remedies, consult the discussions in this chapter on excessive acidity, beginning on page 223.

**Bitter flavor.** This is a common defect. It is associated with inferior milk and poor starter, with excessive moisture and high acidity in the cheese, and with unclean utensils and factory conditions. Using too much rennet causes bitter flavor.

Allen (1930) noticed that bitterness in cheese made from inferior milk developed after 4 weeks and disappeared after 16 weeks. If the inferiority of the milk supply is indicated by the presence of bitter flavor in the milk itself, such milk can be rejected. When the inferiority is indicated by high bacterial content, then the control of the defect must be based on the improvement of the bacteriological condition of the milk; such improvement can be achieved by applying the methylene blue test, resazurin test, or microscopic count.

Proper pasteurization can be applied with reasonable assurance of control when the defect is caused by undesirable organisms in the milk supply. Excessive heat treatments in pasteurizing may actually cause the defect. Phillips (1928) observed that heating milk to temperatures above those required for normal pasteurizing sometimes caused bitter, scorched flavors in the cheese; Moir (1930) made a similar observation.

The organisms added to the milk in starter may cause bitterness. It is possible that single organisms cause the defect; it is highly probable, however, that the defect may also be caused by the combined action of different organisms in the milk and those in the starters.

Hucker and Marquardt (1926) observed bitterness in cheese made with certain strains of acid proteolytic cocci; Deane, et al (1945), on the other hand, reported some very favorable results by using unidentified "acidoproteolytic coccus." Hansen, Bendixen and Theophilus (1933) observed bitterness of flavor when *Streptococcus citrovorus* or *Streptococcus paracitrovorus,* or both, were used in Cheddar cheese. Dahle and Anderson (1940) fortified commercial starter with *S. citrovorus* and produced bitter flavor. Hucker and Marquardt (1926) noticed slight bitterness produced by *S. paracitrovorus* and *S. citrovorus* but they felt that the effect of the former was generally desirable in producing cheese flavor. Harris and Hammer (1940) used numerous cultures of micrococci which had been previously isolated from Cheddar cheese. When they added them to pasteurized milk they found that some of them produced bitter flavors.

Riddet, Valentine, and Whitehead (1932) found that a certain starter which was inclined to be slow, and, at times, metallic and bitter in flavor, produced bitter flavor in cheese. It did not always do so; neither did all slow starters with metallic flavor produce the defect.

In the light of such evidence it is desirable to introduce a new starter into the making operations of a factory experiencing an occurrence of bitter cheese. Such action is especially desirable if the starter shows lack of activity or is faulty in flavor.

Unclean conditions in the handling of milk on the farms or in the factory may cause the bitter flavor defect. Milk cans and utensils should be inspected for rust spots, open seams, milkstone, and other evidences of poor sanitation. The cheese factory utensils, pipelines, vats, whey tank, and can washer should be thoroughly inspected and cleaned. A chemical sterilizer should be used on all equipment immediately before the milk comes in contact with it.

Conditions associated directly with the manufacturing operations may be responsible for bitter cheese; among these are excess acid, excess moisture, lack of salt, and high curing temperatures. Treatments for excess moisture and excess acid are given in this chapter on pages 220 and 224, respectively.

Phillips (1935), reporting on work done with 22 lots of cheese at the University of Wisconsin, observed that bitter flavor occurred most often in Cheddar cheese when the pH at 4 days was 5.00 or less. Price (1936) submitted data that showed a marked correlation between the occurrence of bitter flavor and the presence of slightly excessive amounts of acid in the cheese during making and at four days of age. Maintaining the acidity development at normal limits during making has proved to be an excellent way to reduce the incidence of bitter cheese.

It is generally good practice to reduce the moisture content of cheese in order to minimize or control the effects of undesirable organisms. This procedure is recommended for the bitter flavor defect. Methods of reducing moisture have already been described in this chapter on page 220. The flavor of the curd can sometimes be improved by rinsing with water at 85° F. Aeration of the curd is also helpful.

Tuckey and Ruehe (1940) noticed that bitter flavor was one of the most common defects in cheese exhibits at the Illinois State Fair. This defect was not associated with excessive acid. They varied salting procedures in 10 lots of cheese and found that low salt concentrations were closely associated with bitter flavor. It should be noted that increased amounts of salt delay the growth of some of the organisms in curd and decrease the acidity and the moisture content of the cheese. The addition of the maximum amount of salt is recommended for the bitter flavor defect.

Freeman and Dahle (1938) observed that bitter flavors were associated with ripening temperatures of 63° F. Temperatures of 45° F. were more favorable. Kelly (1932) observed a bitter stage in curing Cheddar that disappeared in continued storage; the flavor appeared at 6 to 8 weeks at temperatures of storage above 50° F. Low temperature storage is recommended for bitter cheese. It is not desirable to attempt to store cheese which shows bitterness during or immediately after making. It is possible that slight bitterness which appears during the early stages of curing may disappear; such cheese however should be carefully watched so that it can be moved into trade channels promptly, if the flavor tends to increase or does not disappear within a few weeks.

**Cowy flavor.** This flavor reminds the cheese judge of the odor of the cow barn. The flavor is in the milk at the intake and becomes more pronounced in the curd because it is apparently absorbed or held by the milk constituents in the curd. It is particularly noticeable at the time of milling. The flavor is present in milk which has been exposed to barn odors by aeration, or by standing in open cans in the barn.

The cowy flavor can usually be detected in milk when it is delivered to the factory. Such milk should be rejected, if the flavor of the finished cheese is to be improved.

Treatments to minimize the defect should include: (1) improvement of conditions of milk production, such as prompt cooling and better protection of the milk; (2) rejection of all milk with a cowy odor; (3) pasteurization of the milk, or use of the Vacreator for this purpose; (4) use of clean, active starter; (5) development of the full amount of acid required by normal cheese at all stages of manufacturing; (6) making cheese with lower moisture content; (7) milling the curd earlier than usual to permit longer aeration of the curd after milling and salting; (8) rinsing the curd with water at 85°F. before salting; (9) using the maximum amount of salt; and (10) curing at temperatures of 45°F. or less.

**Feed flavor.** This flavor in cheese resembles the odor or flavor of a feed eaten by the cow. The odor of the feed is commonly identifiable. It may be present in the milk and it usually becomes more pronounced during the making process. It is particularly noticeable at milling. It may persist throughout the ripening process or it may gradually fade away as more pronounced flavors appear during the ripening of the cheese.

Some feed odors can be readily recognized in the milk; silage, alfalfa, and fresh grass in the spring of the year are common examples; there are many others.

Babcock (1938) reviewed the problem of feed flavors in milk and showed that the intensity of flavor defect varys with the type of feed, amount consumed, and time of feeding. These flavors are imparted through the body of the cow and most of them only show in the milk for a few hours after feeding. Strong feed flavors can be reduced and slight feed flavors can sometimes be eliminated by aeration. Feeds which impart objectionable flavor to the milk should be fed immediately after milking.

Robichaux and Wilster (1941) removed volatile flavors from milk with a Vacreator. This machine heats the milk under reduced pressure. They found that the treatment increased the average score of cheese by 1.05 points.

Treatments to minimize the defects of feed flavor should begin with improvement of methods of feeding the cows. The fault can be minimized by certain factory practices. Rejection of milk with feed flavors is the most effective step. Corrective measures to be applied are identical to those listed on this page, items (3) through (9), for minimizing the effects of cowy flavor.

**Fermented flavors.** These flavors are characteristic of the odor of fermented whey; they possess some of the qualities of the combined odors of alcohol, acetic acid, and propionic acid. They may appear in cheese soon after it is made, but they usually develop after the cheese is two weeks of age. They are believed to be caused by yeasts or bacteria. These organisms may get into the milk on the farms by contact with unclean and non-sterile surfaces of utensils, milking machines, and milk cans. At the factory these organisms may enter the milk through unclean utensils, or undesirable starter, or unsatisfactory sanitary conditions.

It is difficult to detect the presence of the undesirable organisms in the milk at receiving. They are most commonly associated with unclean flavors in the milk and with milk of high bacterial content. A factory experiencing this defect must exercise every precaution in plant sanitation. Milk cans, utensils and equipment should be inspected for open seams, rust spots, milkstone, and any other evidences of neglect. Whey tanks should be subjected daily to careful cleaning and sterilizing procedures. All equipment coming in contact with milk should be sterilized with a chemical sterilizer just before it is used. The water supply should be examined for purity by a bacteriological laboratory.

The defect can be minimized by suitable procedures and treatments during the manufacturing and curing operations. A clean active starter must be used; the defect appears frequently in conjunction with slow acid development. The pasteurization of milk is not wholly effective in preventing the development of this flavor although the condition of the milk is generally improved by the treatment. This fact emphasizes the necessity of strict sanitation to minimize recontamination of the milk in the factory. The normal amount of acid is developed. The moisture content of the cheese is reduced until the defect is clearly under control. The curd should not be rinsed after milling unless it is off-flavored, acid, greasy, or too warm. Water for rinsing the curd should be used cautiously or not at all until proper tests can be made by a bacteriological laboratory. Boards of Health in various states will make such tests or will advise how and where they can be made. Maximum amounts of salt should be used and carefully and thoroughly incorporated. Curing of the cheese at temperatures of 45° F. or less is recommended. During the ripening process the cheese should be watched carefully and moved into trade channels if it is possible to do so before the fermented flavor becomes a prominent defect.

**Fruity flavors.** These flavors were described by Publow

(1908) as resembling those of ripe fruits, such as pineapple, raspberry and the like. These flavors are closely related to the fermented flavor defect. Harding, Rogers, and Smith (1900) produced the defect by adding cultures of selected yeasts. From the standpoint of probable origin, preventions, and remedies they may be considered identical to fermented flavor and should be treated accordingly.

**Moldy flavor.** Moldy flavor in Cheddar cheese is associated with curing conditions. It is caused by the growth of mold in or on the cheese. Mold will grow in Cheddar cheese only when oxygen gains access through openings in the rind, or through openings or cracks inside the cheese which connect with trier holes or others defects in the rind.

Mold grows slowly on cheese held at low temperatures and under dry conditions; it grows rapidly at high temperatures and high humidities. It grows most luxuriantly on non-paraffined cheese. In order to force-cure cheese, it is often deliberately subjected to curing conditions which induce rapid mold growth. Such cheese may show moldy flavor just beneath the rind, even when the mold growth is limited to the surface of the cheese.

Moldy flavor can prevented by storing only properly paraffined cheese which has a close texture and sound rind. Clean boxes should be used for cheese. Temperatures of storage below 45° F., and relative humidities below 75 per cent, minimize the defect. By carefully supervising the cheese during storage, those lots of cheese which show evidence of excessive mold damage can be promptly detected and eliminated.

Some small quantities of mold will always grow on cheese after a few months of storage, even when it is held under the best of curing conditions. Slow growth of mold on the surface of a cheese with a properly paraffined, sound rind will not produce moldy flavor during normal periods of storage.

**Rancid flavor.** Rancidity is the flavor characteristic of the odor of butyric acid. It is believed to be present in all normal Cheddar cheese as one fraction of the characteristic cheese flavor. Lane and Hammer (1939) suggested this possibility after studying the appearance and subsequent disappearance of rancid flavor that had been induced in cheese by making it from mixtures of homogenized raw cream and raw or pasteurized skim milk. These same authors (1940, 1941) pursued this research by adding enzymes from animal tissues to milk for cheese. They obtained encouraging results with small amounts of desiccated, bovine, mammary tissue.

Tuckey (1941) induced rancid flavors by adding homogenized raw cream to pasteurized skim milk and found that they persisted for at least 16 weeks.

The rancid flavor which occurs spontaneously in cheese is highly objectionable to most judges. Hood and White (1931) found during 1930 that 0.85 per cent of Ontario cheese and 1.4 per cent of cheese from the province of Quebec were criticized for rancidity by the graders of the Dominion of Canada, Department of Agriculture. The defect was most prominent in May and least evident in November. They were able to trace most of the rancid cheese to factories receiving low-grade milk. They induced the flavor experimentally by adding organisms capable of producing butyric acid. These organisms, they pointed out, would normally be found in inferior milk and unclean conditions of milk production or cheese manufacturing.

Several phases of the problem of rancid flavor have been studied by Hlynka, Hood, and Gibson (1941, 1943, 1947). They observed that the use of larger amounts of rennet or pepsin in cheese making tended to reduce the degree of rancidity induced by adding a lipolytic enzyme preparation to the milk. This may be particularly significant to manufacturers who add calcium chloride to milk in order to reduce the amount of rennet required for coagulation. These investigators then studied the rancidity induced by agitation of uncooled raw milk; the defect increased with the amount of agitation. At lowered temperatures the agitation was less effective in activating the enzyme. They next tried to inhibit the action of milk lipase by increasing its exposure to acid before cheese making began. The results were partly successful. They explained that the acid itself might inhibit lipase action or it might modify the course of the enzyme action.

The work of Hood and White (1931) suggested that bacteria might be responsible for rancid flavor. Castell (1942) attempted to isolate butyric-acid-producing anaerobes from rancid and normal cheese, because the odor of this acid resembles that of rancid cheese. He found more of them in rancid cheese but not enough more to make the cheese significantly different. Castell and Irvine (1942) actually inoculated milk for Cheddar cheese with butyric acid anaerobes without being able to produce the rancid flavor in the finished product. Irvine (1946) measured lipase contents of clean and slightly rancid cheese but could not detect any significant differences.

The work that has been mentioned points strongly to the significance of the lipase in the milk supply as a possible cause of the rancid flavor defect. Roahen and Sommer (1940) showed that the optimum pH for the action of the milk lipases was 8.4 to 8.6. This is far above that found in cheese. This suggests that lipolysis of the milk fat before the making process begins may be responsible for the rancidity of the finished cheese. The ten-fold concentration of the fat in the making of the cheese suggests that the defective flavors might similarly be concentrated if it were present in the fatty substance.

Krukovsky and Sharp (1938) showed that agitation of milk activated milk lipase. Herrington and Krukovsky (1939) emphasized the necessity of prompt cooling. Krukovsky and Herrington (1939) found that rewarming of cooled milk and then cooling it again accelerated lipolysis. Hlynka, Hood and Gibson (1943) finally showed that unfavorable treatments of milk actually caused rancid flavor in cheese. These findings of these workers indicate a possible approach to the minimizing of rancid flavor in Cheddar cheese.

At this time, when our knowledge of the true causes of rancid flavor is still imperfect, it is only possible to suggest for the control of this defect that: (1) the milk be properly cared for in respect to sanitation, cooling, and protection from excessive agitation; (2) fresh, warm milk should not be mixed with cold milk and then cooled to low temperatures; (3) the milk should be delivered promptly to the factory with as little delay as possible; (4) the milk should be pasteurized to inactivate the milk lipases, if it is to be held overnight before making into cheese: (5) jet-type pasteurizers, which tend to homogenize or disperse the milk fat, should not be used; (6) the ripening time of the milk should be extended to the limits of safety; and (7) the amount of rennet should be increased one and one-half to two-fold; but the usual curd strength at cutting should be maintained by reducing the time from setting to cutting.

**Unclean flavor.** Flavors that are foreign to milk and cheese but which cannot be identified, or otherwise described, are usually called *unclean*. Flavors which resemble the odors that might be imparted to milk by contact with improperly cleaned utensils or equipment are called *unclean*. These flavors may be detected in the milk or may appear in the curd or cheese at any time during making or curing.

Unclean flavors may be caused by any factor that is able to alter the flavor of normal milk without imparting characteristics definite enough to permit recognition of the source. They may be caused by the use of unclean and poorly drained equipment, particularly when such equipment is not sterilized before it is used for handling milk. Hlynka, Hood and Gibson (1941, 1943) have found that cheese graders used the term "unclean" in describing what were probably the first stages or arrested stages of rancid flavor development. Unclean flavors are often attributed to the development of undesirable microorganisms in the milk, curd, or cheese.

The defect may be prevented if the source of the flavor in the milk supply can be identified. Sometimes the flavor can be found in the milk delivered by one or more patrons. Improvement in the bacteriological quality of the milk delivered to the factory is usually beneficial. The sanitary condition of the factory is sometimes a contributing factor. Equipment should be carefully cleaned and sterilized before use. The conditions of drains and floors should be checked to eliminate standing pools of water and foul odors in the factory. The water supply should be tested and approved by the State Board of Health. The cans delivered to the farmers should be clean and sterile, but, in addition, the farmers should be instructed to rinse them with a chemical disinfectant, like chlorine solution, before milk is placed in them. Those conditions which might induce rancidity in milk, such as improper cooling, mixing of night's and morning's milk, and long distance hauling in partly filled cans should be avoided.

Minimizing the defect when it is present in the milk or when it appears in the making of the cheese should include: (1) proper pasteurization of the milk; (2) use of clean, active starter; (3) development of the full amount of acidity for normal cheese at all stages of making; (4) reducing the moisture content of the cheese; (5) rinsing of the milled curd with water at 85°F.; (6) addition of the maximum amount of salt; and (7) cold curing of the cheese.

**Weedy flavors.** These are the flavors produced in milk by weeds in the feed of cows. Examples of such flavors are: onion, leek, bitterweed, and the like. Downs (1940) reported that onion is probably the most common source of weed flavor in milk. He listed ragweed and bitterweed as serious offenders. There may be others not so widely known.

The weedy flavors appear in the original milk or at some stage in the making operation. If they are present only to a slight degree they may be less noticeable or altered in cured cheese when the full cheese flavor develops. Such changes depend to a great extent on the character and intensity of the weed flavor. Lots of cheese with decided weed flavor defects are not good risks in any extensive curing operation; at the end of curing the products are still apt to be low grade.

Treatments to minimize weed defects in flavor should begin with renovation of the pastures producing the weeds. County agents can frequently be called upon for educational assistance to convince the farmers of the necessity for such a good farming practice. Such practices should appeal to the farmer himself because they increase the yield of feed from the land.

When the flavors can be detected in the milk, it should be rejected, and the farmer should be advised to keep the cows away from the weeds long enough before milking to avoid the flavor in the milk. In the treatment of milk with onion flavor, the use of the Vacreator seems to be particularly effective.

Methods of minimizing the effects of weed flavors at the factory are: (1) rejection of defective milk; (2) use of the Vacreator or pasteurization; (3) use of clean, active starter; (4) development of the normal amount of acid required at all stages of manufacturing; (5) making cheese with lower moisture content; (6) aerating the curd after milling and salting; (7) rinsing the curd with water at 85°F. before salting; and (8) curing the cheese at 45°F. or less.

**Yeasty flavor.** This flavor is a type of fermented flavor in which the alcoholic odor dominates. The odor is sometimes noticeable in the milk. It frequently appears first in the curd after the whey is removed. It is usually accompanied by the development of gas holes in the curd and frequently in the cheese.

The yeasty flavor is associated with the growth in the milk of lactose-fermenting yeasts. Harding, Rogers, and Smith (1900) observed that yeasts were usually present in Cheddar cheese showing undesirable, "sweet" flavors. The off flavors were reproduced by using pure cultures of the yeasts in making cheese.

Preventions and remedies for this defect are identical to those listed for the treatment of fermented flavor on page 232; additional suggestions are included in the discussion of yeasty texture, page 248.

## REFERENCES

Allen, L. A. (1930). J. Dairy Res., *2,* 38.
Babel, F. J. (1946). J. Dairy Sci., *29,* 597.
Babcock, C. J. (1938). J. Dairy Sci., *21,* 661.

Brown, L. W. and Price, W. V. (1934). J. Dairy Sci., *17,* 33.

Castell, C. H. (1942). Sci. Agr., *23,* 2:131.

Castell, C. H. and Irvine, O. R. (1942). Sci. Agr., *23,* 3:176.

Dahle, C. D. and Anderson, T. G. (1940). Penn. Agr. Expt. Sta., Bul. 399.

Davis, J. G. and McClemont, J. (1939). J. Dairy Res., *10,* 94.

Deane, D. D., Anderson, T. G., Warren, F. G. and Dahle, C. (1945). Nat. Butter and Cheese J., *36,* No. 1:25.

Downs, P. A. (1940). J. Dairy Sci., *23,* 496.

Freeman, T. R. and Dahle, C. D. (1938). Penn. Agr. Expt. Sta., Tech. Bul. 262.

Hansen, H. C., Bendixen, H. A. and Theophilus, D. R. (1933). J. Dairy Sci., *16,* 121.

Harding, H. A., Rogers, L. A. and Smith, G. A. (1900). N. Y. (Geneva) Agr. Expt. Sta., Bul. 183.

Harris, W. C. and Hammer, B. W. (1940). J. Dairy Sci., *23,* 701.

Herrington, B. L. and Krukovsky, V. N. (1939). J. Dairy Sci., *22,* 127.

Hlynka, I., Hood, E. G. and Gibson, C. A. (1941). J. Dairy Sci., *24,* 561.

Hlynka, I., Hood, E. G. and Gibson, C. A. (1943). J. Dairy Sci., *26,* 1111.

Hlynka, I., Hood, E. G. and Gibson, C. A. (1947). Sci. Agr., *27,* 1:50.

Hood, E. G. and White, A. G. (1931). Dominion of Canada, Dept. Agr., Bul. 146, New series.

Hucker, G. J. and Marquardt, J. C. (1926). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 117.

Irvine, O. R. (1946). Sci. Agr., *26,* 1:7.

Kelly, C. D. (1932). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 200.

Krukovsky, V. N. and Herrington, B. L. (1939). J. Dairy Sci., *22,* 137.

Krukovsky, V. N. and Sharp, Paul F. (1938). J. Dairy Sci., *21,* 671.

Lane, C. B. and Hammer, B. W. (1939). J. Dairy Sci., *22,* 432.

Lane, C. B. and Hammer, B. W. (1940). J. Dairy Sci., *23,* 519.

Lane, C. B. and Hammer, B. W. (1941). Iowa Agr. Expt. Sta., Res. Bul. 291.

Moir, G. M. (1930). J. Dairy Res., *1,* 149.

Phillips, C. A. (1928). J. Dairy Sci., *11,* 292.

Phillips, C. A. (1935). J. Dairy Sci., *18,* 471.

Price, Walter V. (1936). J. Dairy Sci., *19,* 185.

Price, W. V. and Roundy, Z. D. (1934). Nat. Butter and Cheese J., 25, No. 19:24.

Prouty, C. C. (1940). J. Dairy Sci., *23,* 899.

Publow, C. A. (1908). N. Y. (Cornell) Agr. Expt. Sta., Bul. 257.

Riddet, W., Valentine, G. M. and Whitehead, H. R. (1932). New Zealand J. Agr., *44,* 32.

Roahen, D. C. and Sommer, H. H. (1940). J. Dairy Sci., *23,* 831.

Robichaux, R. P. and Wilster, G. H. (1941). Proc. 27th Ann. Meeting, Western Div., Amer. Dairy Sci. Assoc., p. 62.

Tuckey, S. L. (1941). Nat. Butter and Cheese J., *32,* No. 9:12.

Tuckey, S. L. and Ruehe, H. A. (1940). J. Dairy Sci., *23,* 517.

Whitehead, H. R. and Cox, G. A. (1933). Biochem. J., *27,* 951.

## CHAPTER 16

# DEFECTS IN CHEDDAR CHEESE: BODY AND TEXTURE

It is common practice in grading and judging Cheddar cheese to include the characteristics of body and texture under a single heading. It seems logical for the purposes of this discussion to consider each of these properties separately.

### Body

The term **body** is used by technologists in the cheese industry to designate the physical properties of consistency. These properties include firmness, cohesiveness, elasticity, and plasticity. These physical characteristics of cheese are sometimes called **rheological** properties. **Firmness** is the property of the cheese which causes it to resist deformation or distortion under pressure. **Cohesiveness** is the characteristic of the cheese that causes it to stick together. **Elasticity** is the capability of the cheese to recover its size and shape after deformation. **Plasticity** is the quality of the cheese which enables it to be deformed under pressure without rupture.

The rheological properties of cheese are affected by methods of manufacture and composition of cheese. Observations or measurements of these properties are influenced by such factors as temperature and texture of the cheese. Because the quality of the cheese depends to a great extent upon the physical properties of the curd and the cheese, there have been many attempts to develop laboratory methods for measuring these properties. Scott-Blair (1938), Roundy and Price (1941) and Rogers and Sanders (1942) are among those who have developed apparatus and suggested methods for making such measurements.

The technologists of the cheese industry use various terms which indicate firmness, elasticity, cohesiveness and plasticity of curd and cheese. These terms describe the appearance and feeling of the cheese when a plug of it is removed from the cheese with a trier. A normal plug of ripened Cheddar cheese shows a smooth, uniform surface; it feels solid and firm; it does not crumble when cut or pressed; it bends before breaking; and, when rubbed between the thumb and fingers, it feels smooth, and waxy like cold butter.

Some of the common defects in body of Cheddar cheese are listed here in alphabetical order. With each defect are mentioned, in so far as it is possible to do so, its causes, preventions and remedies.

**Corky body.** Cheese with a very firm, hard, tough, and somewhat elastic consistency is called corky. Such cheese is difficult to crush in the fingers, but, when enough pressure is applied, it breaks apart in a woody manner.

Corky body may be apparent as very firm curd at the time of draining; the characteristics usually appear before salting. Corky characteristics may persist throughout the life of the cheese.

Contributing to the production of corky body are such conditions as: low fat content, lack of acid development in making, over-heating during the cooking operation, lack of moisture, and excessive salt content.

Correction of the fault of corky body must restore the normal trend of desirable making operations by: (1) establishing a minimum of 50 per cent fat in the dry matter of the cheese; (2) treating the curd for lack of acid, if the cheese when 3 days of age has a pH of more than 5.3; (3) maintaining a temperature of cooking not over 104°F. for milk with high fat content and not over 100°F. with milk of low fat content; (4) treating the curd for lack of moisture, if the moisture content of the finished cheese is under 35 per cent; (5) using not more than the normal amount of salt indicated in table 13:1; (6) increasing the length of time of curing.

**Crumbly body.** This defect is characterized by the falling apart of cheese when sliced; by difficulty in removing a full plug from the cheese with a cheese trier; and by the breaking of the cheese into pieces or crumbs when crushed between the thumb and fingers. This lack of cohesion is evident through the whole cheese; it is not limited to the surfaces of the curd particles which make up the cheese. Crumbly cheese usually feels firm before breaking. It shatters with a snap like the breaking of chalk. It may feel either dry or moist after crushing.

This defect rarely appears during the making operations, although the first stage of crumbly body may be evident when excessively acid curd fails to mat properly during cheddaring.

The defect is usually apparent in fresh cheese within a week after making; it persists throughout the life of the cheese.

Crumbly body in cheese can be prevented by observing the preventions and remedies for excessive acidity discussed on page 221.

Crumbly body gradually develops in aged cheese and is not regarded as a defect, if the cheese is sweet in flavor. This crumbly body is caused by ripening changes in the proteins and by loss of moisture. This condition is associated only with a fully matured flavor in the cheese.

**Curdy body.** This characteristic is natural in fresh cheese; it is rightly regarded as a defect only when it persists beyond about 30 days. Curdy cheese, when broken apart, reveals the size and shape of the original curd particles after salting. When pressed in the fingers it feels elastic, firm and somewhat like the particles of curd at the time of salting. It cannot be worked together in the fingers after it has once been broken apart.

When curdy body persists in cheese beyond a reasonable time, which is determined by the conditions of ripening, it may be attributed to: (1) low moisture content which delays curing; (2) lack of proper acid development; (3) lack of proper cheddaring in the vat before milling; (4) addition of excessive amounts of salt; or (5) low temperature storage.

The steps which may be required to hasten the disappearance of curdiness are: (1) increasing the moisture content of the cheese as described on page 222; (2) developing the normal amount of acid throughout the making operations; (3) increasing the duration of the cheddaring operation; (4) decreasing the amount of salt to the minimum indicated in table 13:1; and (5) using curing temperatures approximating 45° to 55°F.

**Dry body.** The characteristics of a cheese with dry body are: corkiness, curdiness, and excessive hardness or firmness. The causes of dry body are identical to those for lack of moisture. The elimination of the defect can be achieved by treating subsequent lots for lack of moisture, as indicated on page 222.

**Mealy body.** This characteristic appears when cheese is crushed and rubbed between the thumb and fingers; the structure of the curd looks and feels rough. The characteristic is the opposite of the waxy smoothness desired in normal cheese.

Mealy body can be most readily detected after the curdy characteristics of the cheese have fully disappeared; it is actually apparent during the first week of curing but is not so easily discovered. It persists throughout the life of the cheese.

Mealy body is caused by excessive acidity in the cheese. It may be regarded as a stage of disintegration of crumbly cheese.

Mealy body in cheese can be eliminated in future lots by observing the preventions and remedies for excessive acidity discussed on page 224.

When cheese is held at high temperatures of curing, there develops a roughness of body which resembles mealiness. This characteristic is apparently caused by partial melting of fat and possibly by rapid changes in the degree of hydration of the protein. This form of mealiness usually disappears when such cheese is held at low temperatures for a few weeks.

**Pasty body.** Cheese with this defect is soft in consistency; when pressed and rubbed between the fingers, it quickly becomes salvy, and usually sticky, in consistency; it clings to the fingers.

Pasty body in cheese becomes apparent as soon as the curdy characteristics disappear. The defect is caused by excessive moisture. The preventions and remedies for excessive moisture given on page 220 are applied for the elimination of the pasty defect.

**Sandy body.** This term is synonymous with mealy body.

**Short body.** This term is synonymous with crumbly body and is commonly used only to indicate a slight degree of the crumbly body defect.

**Sticky body.** This term is synonymous with pasty body but is frequently used to indicate only the most objectionable degree of the pasty body defect.

**Weak body.** Cheese with weak body is relatively soft in consistency when pressed between the thumb and fingers. Cheese that is weak in body for some market classifications may be ideal in body for others; the term is relative, not specific, in meaning.

Weak body may be caused by the presence of more than usual amounts of fat in the dry matter of the cheese. This condition is usually indicated by a tendency for the cheese to become excessively oily or greasy when it is pressed and rubbed for a few moments between the thumb and fingers. All cheese becomes oily if the rubbing is prolonged. Weakness of body is most commonly caused by the presence of more than the desired amount of moisture in the cheese.

The elimination of the defect in subsequent lots can be accomplished by reducing the moisture content of the cheese by one or more of the treatments suggested on page 220. Weakness of body may be evidence of only a slight excess of moisture so that only minor adjustments in the making procedure should be required.

### TEXTURE

**Texture** is the term used to describe the manner of union of the particles of cheese. If there are few openings or none at all between the particles, then the texture is said to be **close** or **solid**. If there are spaces between the particles, or if there are voids or openings in the body of the cheese, then the texture is said to be **open**. The terms **close** and **open** used in this way may have another explanation. Cheese is formed by the joining together of the particles of curd in a manner that might be likened to the interweaving of threads in the making of cloth. So the openness of cheese might be described like the texture of cloth. A close texture describes a fabric with no obvious openings, an open or loose texture refers to a fabric with plainly visible openings, for example, a hand-knitted sweater. Texture, as used in this discussion, does not refer to the properties of smoothness, waxiness, elasticity, softness, hardness, or the like; these are characteristics of the body or consistency of cheese.

**Types of open texture.** Cheese may show different kinds of openings; each type has a different origin and so requires different treatments to eliminate it. Round openings in the cheese may appear and grow in size while the curd is still in the vat, or they may not appear until a few hours after making. Cheese with such openings is called **gassy** and is very undesirable. Openings which are slit-like in shape are called **slit-openings**; this defect has been carefully studied in New Zealand, but it is frequently observed in American Cheddar cheese. Openings of irregular shape and size may be found in curd before milling and in cheese immediately after pressing; they are called **mechanical openings.**

**Gassy texture.** Gassy texture in cheese is usually accompanied by undesirable flavor. The cut surfaces of such cheese show round gas-holes which vary from the diameter of a pinhead up to that of a lead pencil. At times the interior of a gassy cheese may have so many holes that it is like a sponge, hence the term, **spongy texture**. Gassy cheese is usually swelled on one of the flat surfaces and sometimes both. Occasionally the cheese may be puffed up like a ball and it may even burst from the pressure exerted by the gas from within.

Evidences of gas sometimes can be detected early in the process. Soon after the curd is cut, it develops an unusual softness instead of the desired firmness. Curd particles may rise to the surface of the whey because of the gas they contain. Such particles, or "floaters," when broken open, may actually show small gas holes or pockets. Gas holes may be seen in the matted curd soon after removing the whey, if gas production is vigorous. They can usually be detected by slicing the matted curd with a sharp knife. Occasionally, when the cheese is milled early, the gas holes escape attention until after the curd is pressed. The undesirable odor and flavor of milk and curd that will become gassy will usually be recognized by a skilled operator in the early stages of making.

**Causes of gassy texture.** Gas-producing microorganisms belonging to the *Escherichia-Aerobacter* group commonly cause the gassy defect in Cheddar cheese. Lactose fermenting yeasts are sometimes responsible for the gassy defect when fermented and yeasty flavors can be distinguished.

Russell (1895) inoculated milk with gas producing organisms and found that the gasses produced were carbon dioxide and hydrogen. He easily detected the gas-producing organisms in the milk used. Whitehead (1930) observed that organisms of the colon group could be added to the milk, just before the making process began, without marked effects on gas or acid development; their effect on flavor however, was undesirable. Crossley (1942) stated that pasteurized milk in factory practice could be free of coliform organisms but that contamination could occur in subsequent handling of milk and curd. The coliform count at milling, he found, ranged from 75,000 to 20,000,000 per gram of curd; at two months of age the cheese showed counts of 10,000 to 220,000 per gram. Yale and Marquardt (1943) observed as many as 900 to 57,000 coliform organisms per gram of pasteurized-milk cheese. Gas holes appeared, according to these workers, when counts of coliform organisms exceeded 10,000,000 per gram, providing no attempt had been made to control them. They observed maximum counts in cheese made from inferior milk; in such cheese counts ranged from 9,900,000 to 410,000,000 per gram, and the organisms persisted for 6 to 12 months.

Yeast may also be the cause of gas openness in cheese. The yeasty odor which accompanies the appearance of the gas holes in the curd is easily identified. Morgan (1930) identified *Torula cremoris* as a cause of openness in factory cheese.

**Preventions and remedies for gassy cheese.** The presence of the gas-producing organisms in the cheese indicates that the surest prevention is elimination of the source or sources of contamination. Such contamination originates in filth and dirt and is propagated by carelessness in handling milk, and by unsanitary conditions of utensils, equipment and factory. The defect usually develops gradually over a period of several days or even weeks. At the first evidence of the unclean flavor of gassy milk, there should be a general clean-up campaign started immediately in the factory and on the farms. Methods of producing milk of high quality have already been described in Chapter 8. At the factory the milk cans, pipelines, pumps, and vats should be inspected for open seams and general cleanliness. All equipment coming in contact with the milk should be sterilized with an approved chemical sterilizer just before it is used. The work of the can washer should be inspected; it must deliver clean, practically sterile cans to the patrons. Patrons should be instructed to rinse these cans with chlorine solution just before milk is placed in them. Whey should never be returned to the farms in the milk cans; a separate set of cans or some other containers should be provided. Whey tanks in factories may be a source of contamination; they should be cleaned and sterilized daily.

Another possible source of contamination is the starter used in making the cheese. The flavor of gas-contaminated starter is unclean; gas bubbles can be detected in the curd, if glass containers are used for seed starters. Gas organisms in bulk starter may sometimes be detected by the foaming of the starter when the curd is first stirred. Even when the presence of gas organisms in starter cannot be detected, it is usually good practice when the cheese is gassy, to obtain new cultures from a reliable laboratory to keep in reserve until the trouble has been corrected.

*At the intake*--increase the inspection given the milk before accepting it. Check the temperature of the milk because at desirable temperatures below 60 F. the growth of organisms is delayed. Smell of every can of milk; gassy milk has the same characteristic, unclean odor which later appears in the cheese. Sediment tests are useful in rejecting unfit milk, but unfortunately they are worthless as an indication of contamination if the milk has been carefully filtered on the farm. The methylene blue test should be applied to every patron's milk. The results will not be available in time to reject the milk, if it happens to be undesirable; but they do point out, within a few hours, those patrons who should be given prompt attention. Any milk which reduces methylene blue in less than three hours should be regarded with suspicion.

Pasteurization destroys gas-producing organisms which are in the milk. This does not protect the milk against subsequent contamination in the factory. Neither does it guarantee the production of high quality cheese. In an emergency the milk can be pasteurized in the cheese vat, if plenty of cold water is available for cooling. Time required for cooling in the cheese vat usually exceeds two hours under the most favorable conditions. Sometimes it is possible to pasteurize only that portion of the milk supply which is suspected of causing the defect. In an emergency a few cans of milk can be heated and cooled in a tank of water.

*At setting*—use the maximum safe amount of clean, active starter. Ripen the milk to the maximum amount of acid that can be used without making the cheese sour. These treatments attempt to establish a dominance of desirable lactic acid organisms and to promote the maximum safe rate of acid development. These objectives are not easy to attain for, in establishing maximum acid development, it is easy to exceed the limits of safety and produce sour cheese. Yale and Marquardt (1943) pointed out that a pH of 5.0 in the curd inhibited growth of gas-producing organisms, but that the acidity was too high to avoid the defects of excess acid. Use one-quarter inch knives at cutting.

*At heating*—stir and cook the curd in the usual manner to make a cheese with low moisture content. Develop maximum acidity before removing the whey; this will be 0.04 per cent more than in the whey after cutting and the curd will show one-eighth of an inch of silky threads on the hot iron. The curd must be well firmed at dipping or the cheese will be sour. The curd can be forked or stirred as the whey is removed in order to reduce the moisture content. This forking should cease before the curd is cooled by exposure.

If the curd floats in the whey after heating, the whey can be withdrawn until the curd rests lightly on the bottom of the vat. Acid will accumulate more rapidly in the whey and there will be a slight extra pressure on the curd; both of these conditions tend to firm the curd.

*At dipping*—arrange the curd in the vat in thin layers which will drain rapidly and so reduce the moisture content of the cheese. Cut the layers into blocks 6 inches wide. Begin piling the curd about 15 minutes sooner than usual and keep the vat covered in the intervals between turnings. From now until milling, the turning and piling of the curd should encourage the development of acid. At the same time, the gas producing organisms will increase in numbers; this is desirable because the purpose of holding the curd in the pack is to give these organisms the chance to pass the peak of their gas producing capacity. Gas holes which appear soon after dipping should begin to flatten out in about one and one-half hours. Continue to turn and pile the curd in the pack until this flattening of the gas holes results in the practical closing of the majority of them. The curd is then ready to mill.

If the packing interval is prolonged beyond the usual time required for normal cheese, the acid development increases beyond the maximum indicated for desirable cheese. This increased acid development does not injure the quality if the curd was properly firmed at dipping, and if the acid was not allowed to exceed one-eighth of an inch at dipping when dipping occurred two hours and thirty minutes after adding rennet. The limit of acid development is indicated by a pH of 6.0 in the curd at packing, and by an increase of 0.09 per cent in titratable acidity in the whey from cutting to packing.

When the gas holes retain their roundness beyond an interval of two and one-half hours after dipping, then a special milling and washing treatment can be applied. The object of milling before the holes flatten out is to permit the escape of gas. The curd is rinsed with three or four pails of water at 100° to 105°F. for each 500 pounds of curd in the vat. The curd is spread over the bottom of the vat after milling and the water is poured over it. The water is drained from the curd as rapidly as possible. This treatment warms the curd and improves its flavor. The milled curd is piled along the sides of the vat and allowed to mat together again into two layers, as at packing. The layers are cut into blocks of any convenient size to handle and are turned and piled as in the usual cheddaring process. When the holes tend to flatten out the curd is ready for milling and salting.

*At milling*–spread the curd out in the vat and stir to eliminate off flavors. The curd is usually greasy and can be improved by rinsing with a few pails of water at 75°F.; this also improves the flavor. Salt in the usual manner after the free whey and wash water cease to run from the curd. Use the maximum amount of salt suggested in table 13:1. Yale and Marquardt (1913) found that both acid- and gas-producing organisms were stimulated in milk cultures by low salt contents but were inhibited by 2% concentration of salt. Put the curd to press as soon as the salt has dissolved. Apply full pressure after pressing and hold the cheese in the press under full pressure for at least 18 hours.

*After pressing*—place the cheese in a room at less than 50° F. Paraffin the cheese when the surface is dry. The quality of such cheese is such that it should not be stored for any length of time. Off flavors develop as the cheese ripens and the keeping properties are inferior.

**Yeasty texture.** Publow (1908) regarded the formation of gas by yeasts as a different defect than that of gassy cheese. He indicated several points of difference in the characteristics of this defect and those produced by the *Escherichia-Aerobacter* group of organisms. He described yeasty-textured cheese as follows: The defect in the green cheese appears first as small, white pin holes. These later grow to form fissures or slits. The flavor of bitterness is found in the milk, curd and cheese. The colored cheese is usually mottled. During the making operations the curd is difficult to firm in the whey. Acid develops slowly at first but very fast during the draining of the whey. After milling the curd is mushy and shrinks slowly. When the contamination is severe the whey in the whey tank may seem to "boil" as though it were heated.

**Preventions and remedies of yeasty texture.** Cleaning up the milk supply, the milk cans, and the factory are fundamental approaches to the correction of yeasty texture. These methods have been discussed in the section in this chapter on gassy texture. Pasteurization of milk can be applied, although it should be repeated here that it is an unsound and undesirable practice to accept milk for cheese making that requires such treatment before it can be made into acceptable cheese. Publow (1908) suggested: the use of clean, active starter, and shortening of the ripening period at setting; more heat in firming the curd; removal of whey as soon as the curd is firmed; low piling of the curd in the pack, except when holes appear; development of more acid in the pack; and slow application of salt to firm the curd and to increase the absorption of salt.

**Mechanical openness in texture.** The openings of irregular shape and size which exist in curd at milling and after pressing are called **mechanical openings**. These openings are exposed by slicing the curd or cheese. They are voids which were formed by the failure of the curd particles or milled curd to unite during matting and pressing. These voids may be almost small enough to escape detection, or they may occupy a space of several cubic centimeters. The number and size of such openings determine whether the cheese will be regarded as defective.

Mechanical openness is regarded as a defect when it is extensive enough to influence the keeping properties of the cheese or to attract the unfavorable attention of the consumer. Openness may affect the keeping properties because changes in color frequently appear first in the voids. If mold penetrates the rind of open cheese it can cause extensive damage because it spreads deeply into the cheese through the openings. Open cheese is frequently the result of careless handling in making, or the application of excessive washing treatments; both of these causes establish undesirable characteristics which tend to decrease the life and quality of the cheese. Sometimes the openness of cheese may attract the consumer; an example is the preference of certain trades for cheese made by the washed-curd process. Such cheese would not be accepted by other markets in which open texture is regarded as undesirable. The openness of cheese is always regarded as a defect when it is so pronounced that it causes the cheese to break or fall apart during slicing and handling.

**Causes of mechanical openness.** This type of openness originates in the physical condition of the curd during matting and pressing. The fault is usually associated with lack of acidity, or lack of plasticity, or both. Contributing factors are: the moisture content of the cheese; the amount of free whey trapped in the curd; washing of curd, as in the washed-curd process; and lack of pressing of the curd. The openness is exaggerated by those factors which tend to increase the development of carbon dioxide in the normal ripening of the cheese such as: slow acidity, inferior milk, and high temperatures of holding at any stage of curing.

The carbon dioxide which develops in the normal ripening of cheese contributes to the openness of the product as it accumulates in the openings and, at times, expands them. Blyth (1882) was aware of the development of carbon dioxide in cheese. Van Slyke and Hart (1902) made measurements which showed that one normal cheese gave off 0.5 per cent of its weight in the form of this gas in 32 weeks; most was released before 20 weeks.

Sherwood (1939) noticed that open cheese developed gas more rapidly than close-texture cheese. He attributed this to the presence of large numbers of gas-producing organisms in the open cheese that were not of the *Escherichia-Aerobacter* group. *Lactobacillus brevis* and, less frequently, *Streptobacterium plantarum* and certain strains of betacocci were involved in the production of "slit-openness." The organisms were present in large numbers around these openings. The slit openness studied by Sherwood does not appear to be identical to mechanical openness and yet is like it in size, place of occurrence, distribution of holes, and in some of the factors contributing to its appearance in cheese.

**Preventions and remedies of mechanical openness.** This defect, like many others in cheese, may originate in the milk itself. Sherwood (1939) thought this was so in his studies of slit-openness. Improving the quality of the milk supply by rigid inspection and applying bacteriological standards to aid in reducing the bacterial content of the supply are the first steps in approaching the solution of this problem. Clarification of the milk has the effect of decreasing the number of openings in cheese but at the same time their size is increased. This fact was observed experimentally by Fisk and Price (1923), Combs, Martin and Hugglar (1924), Wilster (1930) and most recently in commercial practice by Hood and Hlynka (1946).

Starters may be the source of organisms responsible in part for the defect. Hansen, Bendixen, and Theophilus (1933) found that *Streptococcus citrovorus* and *Streptococcus paracitrovorus* used separately or together caused openness in Cheddar cheese. Sherwood (1939) believed that the flavor-producing organisms associated with *Streptococcus lactis* in some commercial starters might at times, be present in numbers sufficient to cause some openness. Prouty and Golding (1946) emphasized this same possibility when they found that *Streptococcus citrovorus* and *Streptococcus paracitrovorus* in lactic starter tended to decrease the vacuum in vacuum-packed Cheddar cheese more than *Streptococcus lactis* or *Lactobacillus bulgaricus.* Under such conditions the use of single-strain starter cultures, so highly favored in New Zealand, offer one means of minimizing the open texture defect (Dairy Research Institute, N.Z., 1937-38).

Treatments in the manufacturing operations to minimize or control the defect of openness are applied to influence the physical condition of the curd, the acidity, and the removal of whey. The common treatments are:

*At setting*—the development of more acid is favored in order to reduce the moisture content of the cheese, to minimize the growth of gas-producing organisms, and to increase the plas ticity of the curd at the time of pressing. More starter is added, the ripening period is lengthened, but, at the same time, every precaution is taken to avoid the development of excessive amounts of acid at this time or later in the process.

*At heating*—no change in the normal temperature is required for the treatment of the defect. It is very desirable that the firmness of the curd should be well ahead of the acid development before the whey is started from the vat. When the curd is properly firmed after heating, all stirring is stopped; the curd settles, and, as fast as possible, it is arranged for draining. The trench for draining is formed as usual by pushing the curd from the center toward the sides of the vat. The curd is arranged at this time so that it will not be necessary to break it apart by further handling when the whey is finally drawn.

*At dipping*—the curd should have nearly the maximum amount of acid; it must be properly firmed. Stirring of the curd to firm it at this time is beneficial only if the moisture content is higher than desired. As soon as the curd layers are revealed by the removal of the whey, the edges are squared off by trimming with a cheese knife to promote uniform matting. The trimmings are placed on top of the curd layers and allowed to mat with a minimum of handling. These trimmings should be in strips not more than one inch in thickness so they can be spread uniformly over the rest of the curd without making some sections too thick. The depth of the curd at this time approximates 7 inches; cutting the curd into strips and doubling them up to a depth of 14 inches while the last of the whey is removed tends to trap large amounts of whey in the curd. This treatment is undesirable because it increases the moisture content of the cheese and tends to form whey-filled openings in the curd. The acidity of the curd at this time is normal for Cheddar of high quality.

*At packing*—and *during cheddaring*—the handling of the curd is designed to keep the temperature uniform, to develop a smooth silky surface on all sides of each block, to encourage normal acid development and moisture control, and to promote uniform cooling of all parts of the curd. This is achieved by cutting the curd into blocks of normal size and turning them at regular intervals. At each turning of the curd the blocks should be reversed so that the cooler ends are rewarmed against the side walls of the vat. The piling of the blocks is delayed for 15 to 30 minutes longer than usual in order to permit more thorough draining of the free whey. The curd is carried longer in the pack before milling to develop more acidity and more uniform plasticity. Ends of the blocks should be as smoothly cheddared as the rest of the block. Cutting across the block of curd with a sharp knife just before milling should show few, if any, holes in the cut surfaces.

*At milling*—the curd is stirred enough to prevent matting, and salt is withheld until the free whey has drained from the vat. The curd at this time is plastic, mellow and smooth. Any greasy condition is corrected by lightly rinsing with water at 90°F. Waiting an hour before salting gives close texture.

*At salting*—it is desirable to increase the amount added. Riddet, Valentine, McDowall and Whelan (1933) pointed out that undersalting encourages open texture in Cheddar cheese and that oversalting gives close texture, harsh body, slow ripening and cracked rinds. The salt is applied in two or three applications, and the curd is then spread out in the vat to permit drainage of whey. This period is important because free whey, if present in large amounts in the curd at pressing, is trapped in the body of the cheese; later it is absorbed but the void remains. Another reason for delaying the pressing of the cheese is to permit the curd to regain the smooth, silky surface and mellow body that characterized it before salting.

*At hooping*—Riddet and Valentine (1932) found that the manner of packing curd in hoops influenced the texture of the cheese. They advocated that the curd should be firmly packed into the cheddar style of hoop. Only a small portion of curd should be added at one time and that should be punched down firmly into the hoop. Even a well-firmed and properly drained curd, they indicated, showed whey running from the hoop, when the filling was properly done.

*At pressing*—the temperature of the curd approximates 85°F. to 90°F. Pressing the curd when it is too warm encourages the development of gas-forming organisms, while low temperatures at pressing tend to harden the curd and make it more difficult to press together. A smaller size of hoop can be used in some instances to eliminate openness. This situation may occur when the pressure applied to the larger hoops is inadequate to close the cheese. Free moisture is more readily expressed from small loaves of cheese for the same reasons that it is easier to wring the water out of a wash cloth than out of a towel. The Dairy Research Institute, N.Z. (1945-46) reported experiments showing that constant high pressure of 150 pounds per square inch over night practically eliminated all mechanical openness in normal, well-made cheese. It should be remembered that New Zealand cheese normally contains only about 33 per cent moisture or less.

*After pressing*—the cheese is placed in a cool drying room at 45 F. before paraffining. This treatment delays the normal development of carbon dioxide which takes place most vigorously at this time. If the gas is produced at a rate which permits its diffusion from the cheese then any openings are not enlarged. Holding at 60 F. causes more openness, according to Riddet. McDowall and Valentine (1933), than cooler temperatures. Continuing storage with low temperatures of holding tends to minimize the effects of ripening agents which promote openness in the cheese.

## REFERENCES

Blyth, Alexander Wynter (1882). Foods: their composition and analysis. London, Griffen and Company.

Combs, W. B., Martin, W. H. and Hugglar, N. A. (1924). J. Dairy Sci., *7,* 524.

Crossley, E. L. (1942). Proc. Soc. Agr. Bact., (Gr. Brit.), 16.

Dairy Research Institute, New Zealand, (1937-38). Annual Rept., Dept. Sci. and Ind. Research, Publication 114.

Dairy Research Institute, New Zealand, (1945-46). Annual Rept., Dept. Sci. and Ind. Research, Publication 200.

Fisk, Walter W. and Price, Walter V. (1923). N. Y. (Cornell) Agr. Expt. Sta., Bul. 418.

Hansen, H. C., Bendixen, H. A., and Theophilus, D. R. (1933). J. Dairy Sci., *16,* 121.

Hood, E. G. and Hlynka, I. (1946). Nat. Butter and Cheese J., *37,* No. 1:38, and *37,* No. 2:39.

Morgan, G. F. V. (1930). New Zealand J. Agr., *40,* 178.

Prouty, C. C. and Golding, N. S. (1946). J. Dairy Sci., *29,* 495.

Publow, C. A. (1908). N. Y. (Cornell) Agr. Expt. Sta., Bul. 257.

Riddet, W., McDowall, F. H., and Valentine, G. M. (1933). New Zealand Dept. Sci. and Ind. Research, Bul. 38.

Riddet, W. and Valentine, G. M. (1932). New Zealand Dairyman, *36,* No. 5:54.

Riddet, W., Valentine, G. M., McDowall, F. H. and Whelan, L. A. (1933). New Zealand Dept. Sci. and Ind. Research, Bul. 37.

Rogers, L. A. and Sanders, G. P. (1942). J. Dairy Sci., *25,* 203.

Roundy, Z. D. and Price, W. V. (1941). J. Dairy Sci., *24,* 135.

Russell, H. L. (1895). Wis. Agr. Expt. Sta., 12th Ann. Rept., 139.

Scott-Blair, G. W. (1938). J. Dairy Res., *9,* 347.

Sherwood, I. R. (1939). J. Dairy Res., *10,* 326.

Van Slyke, L. L. and Hart, E. B. (1902). N. Y. (Geneva) Agr. Expt. Sta., Bul. 231.

Whitehead, H. R. (1930). J. Dairy Res., *2,* 76.

Wilster, G. H. (1930). Nat. Cheese J., *22,* No. 11:10.

Yale, M. W. and Marquardt, J. C. (1943). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 270.

## CHAPTER 17

# DEFECTS IN CHEDDAR CHEESE: COLOR AND FINISH

The first impression of the quality of cheese is created by its outward appearance. The consumer is interested in the color of the cheese when it is cut and ready to serve; it is the first characteristic to attract his attention. The dealer in cheese is first impressed by the exterior finish of the product; it frequently indicates important facts about the quality and keeping properties of the cheese.

### COLOR

Normal Cheddar cheese has a uniformly colored interior when it is sliced or examined on the trier. It is translucent in thin slices. At the rind end of the cheese there is normally a narrow band of slightly darker color. This band is broad in cheese which has been held for a long period without paraffin, or in a dry storage room, or on an open shelf rather than in a box. When conditions of humidity surrounding the cheese have delayed evaporation, then this band of darker or amber colored cheese may be lacking or almost invisible.

**Acid-cut.** The color of the interior of cheese may be lighter or whiter than normal; it lacks normal translucence; such color may be induced by excessive amounts of acid in the cheese and is therefore called **acid-cut**. The defect may also be known as **bleached** or **pale color**. This defect may appear soon after the cheese is made but is most easily detected when the acidity of the cheese reaches its maximum during the first week after making. It occurs in both colored and uncolored cheese but is more easily detected in the colored cheese.

There is no remedy for acid-cut color in Cheddar cheese. Prevention of the defect depends upon the control of acidity during the manufacturing operations; such controls of excessive acidity have been discussed on page 224.

**Black discoloration.** Black spots in Cheddar cheese were attributed to the presence of minute traces of lead by Leitch

(1927). The principal sources of such lead he believed were from the lead in the paint used on the walls of the steam jacket and from solder used in the seams of the vat. He also found lead present in the annatto color (Leitch 1929). Morgan (1930) attributed the black discoloration in cheese with annatto color to the action of microorganisms on the lead salts in the annatto extract.

Most cheese makers have observed the black discoloration in cheese that occurs when particles of steel wool used in cleaning equipment find their way into the curd. Such abrasive material is not suitable for cleaning. Hood and White (1930) commented on this cause of discoloration.

**Bleached discoloration.** A bleached discoloration, which is not attributable to excessive acid content, appears only in colored cheese (Morgan, 1931, 1933). Morgan (1931) associated the defect with the reducing action of such organisms as *B. subtilis* and *B. fluorescens liquefaciens* on the annatto dye. He observed that these bleached areas changed to a muddy discoloration upon longer holding. The fault was found near cracks and trier holes and, though not moldy themselves, these areas were usually connected by cracks to moldy plug holes in the cheese. He found that the bleached color turned pink and finally red as the discoloration progressed; the smell of undesirable odors like hydrogen sulfide developed with the defect.

Moir (1933) believed that the bleaching was probably associated with changes in the fat and that the advanced stages of the discoloration could be explained by the diffusion of mold enzymes into the cheese from the centers of mold growth.

Barnicoat (1937) confirmed the observations of these workers but felt that his investigations of the nature of the chemical properties of annatto did not encourage the idea that the discoloration would be caused by the reducing actions of the bacteria present. This type of bleached discoloration could be minimized by protecting the cheese from plugging faults and by covering trier holes with hot paraffin.

A bleached discoloration sometimes appears on rindless cheese in flexible wrappers. It is possible that this defect is associated with incipient development of mold, diffusion of enzymes of mold mycelia, or with the growth on the surface of the cheese of certain bacteria, like those mentioned by Morgan (1931). This defect in packaged cheese, however, has not as yet been studied extensively.

**Mottled cheese.** Mottled color in cheese is frequently caused by the mixing of curd from two vats. This can be avoided without loss of curd and with minimum variations in the weight of the normal cheese by pressing excess curd in a smaller style of hoop. Publow (1908) attributed mottled color to manufacturing faults such as: uneven development of acid and moisture, neglecting to strain lumpy starter, adding starter after color, uneven piling of curd, lack of stirring at salting, and the like. To this list should be added the possibility that returning uncolored curd from rennet tests to a vat of milk, which is subsequently colored, can also produce white spots in cheese.

Udy (1931) observed that mottled color might be caused by the bleaching action of direct sunlight falling on a colored vat of milk. We have not been able to confirm this observation although the bleaching action is very marked on the surface of curd when sunlight shines directly across the vat in the brief interval between coagulation and cutting.

Hood and White (1929) reported an investigation of mottled color in Canadian cheese. The defect was reported in both colored and uncolored cheese but was apparently more noticeable in the colored cheese. The affected cheese showed different intensities and hues of color, such as pink, reddish, brown, and muddy shades; uncolored cheese showed the muddy shades. Their analyses revealed nitrates or nitrites in the cheese, while bacteriological examination indicated the presence of nitrate reducing organisms capable of producing the discolorations. The nitrates in the form of saltpeter had been added to the milk to conceal defects in milk quality. These workers condemned the practice, for obvious reasons.

**Rusty spots.** This defect was described by Harding, Rogers, and Smith (1900). They likened the spots to iron rust in appearance and said they were evenly distributed throughout the cheese. They did not find them in very young cheese and observed that they grew in size as the cheese aged. The trouble was most common in spring and fall. The organisms causing the defect grew on the walls of openings in the cheese. Davis and Mattick (1929, 1930) isolated and described an anaerobic, lactic acid producing organism able to produce the rusty pigment in Cheddar cheese. They found that such factors as: oxidation-reduction potential, moisture, fermentable carbohydrate, all influenced the pigmentation of the organism. Breed and Pederson (1938) and Pederson and Breed (1941) made further studies of the organisms and decided that they consisted of two species:

some were chromogenic variants of *Lactobacillus plantarum*, others were variants of *Lactobacillus brevis*.

Prevention of this defect in cheese depends upon strict factory sanitation; cans, utensils, and equipment must be cleaned and sterilized. Floors and drains should be given special attention: they should be repaired, if necessary, to eliminate pockets where whey or floor drainage might accumulate. Insects and rodent pests and their breeding places inside and outside of the factory should be eliminated. In the making operations: (1) use a clean active starter; (2) make a close textured cheese; and (3) make colored cheese to minimize the contrast between the spots and the remainder of the cheese.

**Seamy color.** Cheese in which the particles of curd are outlined in light colored lines is said to have seamy color. The defect occurs in both colored and white cheese and is apparent when the cheese is taken from the press. The seaminess of fresh cheese tends to decrease as the cheese ages. The defect is caused by greasy curd, rapid addition of salt, lack of stirring of salt after each application, or pressing of the curd too soon after salting.

Prevention of the seamy color defect depends upon proper manipulation of the curd during the process of manufacture: (1) permitting the curd to cool slowly to temperatures approximating 90°F. at milling and 85°F. at pressing; (2) reducing the stirring of the curd after milling to a minimum in order to prevent excessive losses of fat from the milled curd; (3) rinsing the curd with water at 90°F. or slightly cooler, if the curd is greasy or too warm; (4) adding the salt in three applications and distributing each application by careful stirring; (5) avoiding the application of steam under the pan of the vat during the period immediately before, or any time after milling; (6) holding the curd before pressing until it feels smooth and silky; and (7) allowing complete drainage of whey from the salted curd before placing it in the hoops for pressing.

**Wavy color.** This defect may be considered to be a modification of mottled color and should be so treated for prevention. It is frequently observed when the defect is caused by lack of control of acid development during the making of the cheese; the cheese may be either too sweet or it may contain too much acid.

The defect may occur in stirred-curd cheese; it is caused by the lumping or matting of the curd into balls before salting. The preventive measure required is more vigorous stirring.

**White specks.** When cheese is cold-cured it frequently develops small white specks. These particles may be so small that they can scarcely be detected, or they may grow to the size of small peas. They are irregular in shape and appear to be aggregates of the white substance rather than crystals. They are hard and gritty and, when present in large numbers or as excessively large particles, they must be considered as a defect. Judges are not critical of their presence until they interfere with the enjoyment of eating the cheese.

Babcock, et al. (1901, 1902) commented on the common occurrence of white specks in cheese cured at low temperatures. They noticed that they did not appear when the cheese was cured at 60° F., and that increased amounts of rennet and salt tended to decrease their formation. They observed the specks abundantly in skim milk cheese but not at all in cheese rich in fat.

Tuckey, Ruehe, and Clark (1938) showed by x-ray analysis that these white specks in Cheddar cheese had the same characteristic structure as calcium lactate. McDowall and McDowell (1939) analyzed the specks and found that they were chiefly calcium lactate to which cheese material adhered in the form of fat, protein and moisture. Dorn and Dahlberg (1942) scraped white particles from the parchment paper used in wrapping Cheddar cheese for canning. They stated that the same substance occurred in the holes and cracks of the cheese. The chemical properties of the material were characteristic of the amino acid, tyrosine. They believed that the calcium and phosphorus in the ash of the white material suggested that calcium phosphate salts were present as impurities in the specks of tyrosine.

## Finish or Appearance

Normal Cheddar cheese has a smooth, unbroken rind and a neat, clean attractive appearance. These attributes are collectively called the **finish** of the cheese. A perfect finish indicates the exercise of skill throughout the making operations. Finish is important because it affects the keeping properties and the merchandising value of the cheese.

Some of the common defects in finish of Cheddar cheese are listed in alphabetical order in the paragraphs which follow. The causes, preventions and remedies for each defect are mentioned when it is possible to do so.

**Checked or cracked rind.** When openings occur on any part of the cheese surface, the cheese is said to have a **cracked rind.**

When the openings are small and apparently located between the particles of curd in the rind, then the small cracks are sometimes called **checks.**

This defect may appear at any time after the cheese is removed from the press. It usually appears before the cheese is paraffined. It sometimes appears after paraffining when the protective coating of wax has been broken, removed, or scaled off.

This defect is caused by excessive evaporation of moisture from the surface of the cheese and by weak bonding together of the curd particles in the rind of the cheese. Factors contributing to rapid evaporation of moisture are: (1) high temperatures in the drying room; (2) low relative humidity; (3) rapid circulation of air; and (4) early removal of cap cloths. Factors contributing to weak bonding of the curd particles are: (1) excessively low or high acidity; (2) greasy curd; (3) excessive salt (Riddet, et al. 1933); (4) wrinkled and folded bandages and cap cloths; (5) bandages not covering all the cheese surfaces; (6) nonabsorbent and thin bandages and cap cloths; (7) mixing curd from two days' makes; (8) lack of pressing; (9) rapid chilling of curd in press; (10) pounding cheese out of the hoops; and (11) any handling which distorts the shape of the cheese (Dolby, 1941).

Preventions and remedies depend upon the cause or causes of the defect. When excessively rapid evaporation occurs before the cheese can be paraffined: (1) reduce the temperature of holding below 60°F.; (2) increase the relative humidity to more than 60 per cent by keeping the floors wet or by using a mechanical humidifier; (3) slow down the circulation of air by shutting off blowers, and reducing the amount of ventilation; (4) keep cap cloths on the cheese until paraffining; (5) turn cheese daily; and (6) reduce the time of holding before paraffining.

When the cause of cracking is weak bonding together of the particles of curd in the rind: (1) check the condition of the cheese for lack of acidity, or for excessive acidity, and follow the usual measures of control; (2) rinse greasy curd lightly with water at 90°F.; (3) reduce the amount of salt but use not less than the minimum suggested in table 13:1; (4) dress hoops carefully to avoid wrinkled bandages; (5) use the best quality of bandage and clean, porous cap cloths or press cloths; clean cap cloths with milkstone remover, if necessary, to keep them soft and porous; (6) avoid pulling bandages too high on the sides of the cheese in dressing; (7) use plenty of clean water at 120°F. in dressing the cheese; (8) do not hold over curd from one day to the next; use extra curd to make a small style, if necessary; (9) press the cheese with continuous pressure for at least 12 hours; (10) protect the cheese against chilling in the press by keeping the factory warm and keeping the press away from cold areas, such as beneath windows; (11) loosen the cheese in the hoop with a speed knife before turning it out of the hoop; this avoids unnecessary pounding and consequent rupturing of the rind formation; (12) avoid all rough handling of the cheese or any treatment that tends to distort the cheese such as: piling cheese, one on another; dropping them on edge; throwing them on a truck; and bending them by lifting on the edges.

If cheese shows checks when it is taken from the hoop, it should be repressed. First straighten out the bandages, starched circles, and cap cloths. As these cloths are smoothed out, thoroughly soak them and the cheese with water at 120°F. When the cheese is replaced in the hoop, some of the warm water can be poured into the hoop before the follower is replaced, in order to warm the hoop and the cheese surfaces and to remove excess fat from the bandages. Press the cheese as long as possible.

Cheese with checks should receive special care during paraffining in order to close all checks with the wax. Badly checked cheese can be reparaffined after it has been thoroughly chilled.

**Dirty finish.** Cheese may become dirty as it leaves the hoop or at any time after that operation. This condition can be easily avoided by: (1) using clean hoops that are free of rust; (2) keeping the press clean; (3) using clean hands or clean gloves to handle the cheese; (4) keeping the curing room shelves clean; and (5) preventing the carrying of coal dust or dirt into the curing room by air currents or otherwise.

**Greasy finish.** Grease may appear on the surface of the cheese during or after the pressing operation. Occasionally the cheese becomes greasy after paraffining. This condition is undesirable when the cheese must be handled, and it is unsightly.

Grease on the surface of the cheese as it is removed from the press originates in overheating or overstirring of the curd at the time of milling or salting. The rinsing of the curd with water at 90°F. and the use of lower temperatures at pressing tend to correct the fault. Cheese stored before paraffining at temperatures over 60°F. tend to become increasingly greasy as the time and temperature of holding increase. Cheese that have been paraffined will become greasy during curing if they are held at temperatures of 55°F. or more.

**Huffed finish.** Cheese that is excessively bloated by gas formation is called **huffed.** This defect can be prevented by following the suggestions for gassy defect on page 244. The gas sometimes collects in blowholes in the cheese and by perforating the cheese with a knitting needle and inverting the cheese on the shelf, the gas can be expelled. The cheese is not improved by this procedure, although it may be changed in shape enough to permit boxing. This needling treatment opens the cheese to mold growth so that the cheese must be used quickly to prevent even more extensive damage.

**Loose paraffin, scaly paraffin.** Paraffin may tend to chip or scale from the cheese surface at any time after paraffining. After it has been stored for a short period it may seem to loosen in large areas; it can sometimes be rubbed from such areas, exposing wet rind.

The causes of loose paraffin suggest the remedies. (1) Excessive moisture makes cheese weak in body; such cheese is easily distorted in handling; if the flexibility of the paraffin layer breaks under such distortion, it tends to chip or scale from the cheese. (2) A wet cheese surface at the time of paraffining causes the wax to adhere less firmly or not at all in the wettest spots. Moisture under paraffin encourages **rind rot,** another defect in finish. Such wet surfaces come from excess moisture in the cheese, too much or not enough acid in making, inadequate drying, lack of turning before paraffining, or condensation of moisture on the surface of cheese brought out of a refrigerator into a warm, moist room for paraffining. (3) When the layer of paraffin is too thick it tends to loosen, break, and chip. This may be caused by too low a temperature of paraffining, holding the cheese in the paraffin too short a time, dipping the cheese when it is too cold, use of a wax with excessive viscosity when hot, or by repeated dipping of the paraffined cheese. (4) A loose or folded bandage, or starched circle eventually gives way and causes the paraffin to loosen. Loose starched circles and bandages should be cut away or removed from the cheese at the time of paraffining. (5) Tiny blister-like areas in or under the paraffin surface tend to chip from the cheese. These blisters may be caused by beads of moisture on the surface of the cheese or in the paraffin itself at the time of dipping. Such droplets of moisture may occur as condensate on cold cheese, or they may get into the paraffining tank from leaking steam coils.

**Moldy cheese.** Cheese may become moldy within a few days after making or at any time after paraffining. Mold growth before paraffining can be minimized by: (1) keeping the drying room shelves varnished, clean, and dry; (2) turning the cheese daily; (3) reducing the humidity of the drying room by proper ventilation and removal of condensate from refrigeration coils by piping it to drains; (4) paraffining the cheese as soon as the surface of the cheese is dry. Molding of cheese after paraffining can be delayed or prevented by: (1) paraffining at temperatures approximating 235° F.; (2) sealing, by brushing with hot paraffin, the scars where the cheese rested on the paraffining rack; (3) using clean, dry boxes; (4) holding the cheese for cold curing at temperatures approximating 35° F.; (5) turning the boxes of cheese at suitable intervals to prevent the accumulation of moisture at the bottom of the box. The intervals between turning depend on the temperature and humidity of storage and the condition of the cheese; they can only be determined by frequent regular inspections of the cheese.

Mold on shelf-cured cheese is not always considered to be a defect but rather is sometimes regarded as an indication of the success of the treatment. Such cheese may be held, usually without paraffining, at temperatures of 56° to 60° F. The relative humidity is kept at approximately 88 per cent and the cheese is turned often enough to obtain uniform mold growth on all surfaces of the cheese. The uniform growth of mold gives a black finish on the cheese when it is finally paraffined. Such cheese is usually moved promptly into trade channels after it has been paraffined.

**Rind rot.** The development of wet, soft spots or areas on the surface of the cheese directly under the paraffin indicates the beginning of rind rot. Such conditions encourage the growth of putrefactive microorganisms which soon develop foul odors in these areas. These odors eventually diffuse throughout the cheese.

Rind rot may be caused by: (1) excessive moisture; (2) excessive acidity and high moisture combined; (3) any condition which permits mold or cheese mites to grow beneath the paraffin; (4) lack of turning of the cheese during storage. The causes of rind rot that have been mentioned suggest their own remedies. The penetration of molds and mites beneath the paraffin promotes rind rot because both agents decrease the acidity of the cheese and encourage the growth of putrefactive organisms. Frequent inspection of cheese in storage and prompt removal of suspicious lots tends to minimize losses by this defect.

**Trier marks.** When a trier is used to obtain a sample of cheese for analysis or grading, the sound rind is broken and the cheese is damaged, even when the rind end of the plug is restored to the cheese. The extent of this damage varies with the number and location of trier holes, the time of plugging, and the treatment of the scars. Several plugs taken from a restricted area introduce enough oxygen to support mold growth inside of the cheese; such plugging is seldom essential and cheese plugged in this manner should not be held in storage. When cheese is plugged shortly after it is removed from the press, the drying of the rind causes the plug in the trier hole to shrink; this condition is especially damaging but may be avoided in part, by applying petrolatum over the scar. Cheese should be plugged just before paraffining, if it is possible to do so. When cheese is plugged after paraffining, the rind end of the plug should be carefully restored and the marks of the trier should be brushed with hot paraffin, or sealed with soft wax.

**Uneven color.** An uneven color on the surface of the cheese can be regarded as a surface defect. Abnormally light-colored areas are caused by: (1) excess acid; (2) excess moisture in the rind area; (3) uneven application of paraffin; (4) loose paraffin over rind rotted areas; and (5) mixing of two lots of curd. Dark colored areas are caused by: (1) mold growth on or beneath the paraffin; (2) excessive drying; (3) mixing of two lots of curd; and (4) use of sodium or potassium nitrate in the making of the cheese.

**Uneven surfaces.** Cheese which is out of shape is criticized for uneven surfaces. This defect may be apparent when the cheese is taken from the hoop or it may develop in the curing process. Uneven surfaces commonly observed are: lopsided, sloping flat surfaces, and rough finish on the follower side of the cheese.

The lopsided defect usually appears during the curing of the cheese and can be caused by excessive moisture content, lack of salt, high temperatures in the curing room, or lack of rack support for the longhorn style of Cheddar. Cheese with sloping, flat surfaces, sometimes called "hillside" cheese, may be caused by uneven distribution of the curd in the hoop, pressing the cheese so slowly that the curd settles to the lower side of the hoop before it is compressed, and by an uneven head block or tail block in the press. Rough finish on the follower side of the cheese consists of a ring of curd at the edge of the cheese which squeezes up around the edge of the follower.

Methods of preventing uneven surfaces are the best treatments of the defect; they require: (1) adjustment of moisture content of the cheese to conform to the conditions of curing and marketing; (2) use of the full amount of salt to avoid weak-bodied cheese; (3) careful filling of the hoops; (4) pressing the cheese promptly and fully as soon as the hoops are turned on edge in the press; (5) using followers which fit the hoops, or adjusting the amount of cheese in the hoops so that the followers will settle snugly into the tapering sides of the hoops; (6) reducing the temperatures of holding the cheese to give the cheese more solidity of body; (7) providing lateral racks to hold upright the longhorn style of Cheddar while it is drying before paraffining.

The faults of uneven surfaces can be corrected when the cheese is removed from the press by the following operations: (1) loosening the bandages; (2) warming the surface of the cheese by rinsing it with liberal amounts of water at 120°F.; (3) replacing and smoothing the bandages, starched circles, and cap cloths; and (4) repressing the cheese until it is properly reshaped by the hoops. It is sometimes desirable to reverse a cheese in the hoop so that the follower side is repressed into the small end of the tapering style of hoop. Crooked head blocks and tail blocks must be straightened to avoid repetition of the faults.

**Wrinkled bandage.** This defect is apparent when the cheese is removed from the press. The wrinkles may be on the flat or rounded surfaces of the cheese. Wrinkles or folds in the bandage, starched circle, or cap cloth may be caused by: (1) a long bandage which laps too far over the top or bottom of the cheese; (2) dressing the cheese before the curd has pressed together; (3) failure to adjust the bandage, starched circle, or cap cloth in dressing the cheese; (4) careless handling of the hoops in the press. These faults in the order named, can be prevented or corrected by (1) using a bandage of the right length, or adjusting the bandage so that it overlaps an equal amount on each end of the cheese; (2) applying full pressure to the cheese in the press for a period of 20 minutes or more before dressing; (3) pulling up the bandage around the cheese in the hoop during dressing until every wrinkle is removed; (4) placing the follower firmly on the dressed cheese and maintaining enough pressure on it, when the hoop is turned on edge in the press, to keep the cap cloth and starched circle firmly in place—using plenty of warm water to wet these cloths during dressing is an advantage in this operation. Wrinkles in the bandage, starched circle, or cap cloth can be corrected by warming the surface of the cheese with water at 120 F. and then redressing and repressing the cheese.

## REFERENCES

Babcock, S. M., Russell, H. L., Vivian, A. and Hastings, E. G. (1901). 18th Ann. Rept. Wis. Agr. Expt. Sta., 162.

Babcock, S. M. and Russell, H. L. (1902). Wis. Agr. Expt. Sta., Bul. 94.

Barnicoat, C. R. (1937). J. Dairy Res., *8,* 61.

Breed, R. S. and Pederson, C. S. (1938). J. Bact., *36,* 667.

Davis, J. G. and Mattick, A. T. R. (1929). J. Dairy Res., *1,* 50.

Davis, J. G. and Mattick, A. T. R. (1930). J. Dairy Res., *1,* 136.

Dolby, R. M. (1941). New Zealand J. Sci. Technol., *23,* 194A.

Dorn, F. L., and Dahlberg, A. C. (1942). J. Dairy Sci., *25,* 31.

Harding, H. A., Rogers, L. A. and Smith, G. A. (1900). N. Y. (Geneva) Agr. Expt. Sta., Bul. 183.

Hood, E. G. and White, A. H. (1929). Dom. Can. Dept. Agr., Bul. 128. New series.

Hood, E. G. and White, A. H. (1930). Dom. Can. Dept. Agr., Bul. 79. New series.

Leitch, R. H. (1927). Scot. J. Agr., *10,* 165.

Leitch, R. H. (1929). Scot. J. Agr., *12,* 308.

McDowall, F. H. and McDowell, A. K. R. (1939). J. Dairy Res., *10,* 118.

Moir, George M. (1933). J. Dairy Res., *4,* 238.

Morgan, G. F. V. (1930). J. Agr., *40,* 178.

Morgan, G. F. V. (1931). New Zealand J. Agr., *42,* 35.

Morgan, G. F. V. (1933). J. Dairy Res., *4,* 226.

Pederson, C. S. and Breed, R. S. (1941). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 259.

Publow, C. A. (1908). N. Y. (Cornell) Agr. Expt. Sta., Bul. 257.

Riddet, W., Valentine, G. M., McDowall, F. H. and Whelan, L. A. (1933). New Zealand Dept. Sci. Ind. Res., Bul. 37.

Tuckey, S. L., Ruehe, H. A. and Clark, G. L. (1938). J. Dairy Sci., *21,* 161.

Udy, W. H. (1931). New Zealand J. Agr., *42,* 244.

## CHAPTER 18

# JUDGING AND DESCRIBING THE ATTRIBUTES OF CHEDDAR CHEESE

The **judging** of cheese is the act of estimating and evaluating its attributes or characteristics. When the attributes of the cheese are used to classify it into groups of similar quality, the act of judging is called **grading.** When the attributes of the cheese are rated in terms of points or numbers, the act of judging is called **scoring.**

Judging cheese is a necessary step in the merchandising of the product to determine its commercial value; grading is usually relied upon for this function. Scoring of cheese is commonly used to make careful distinctions: (1) between products offered in competition for prizes; (2) between products made under different conditions, or by different methods in order to evaluate in terms of quality the effects of the conditions or methods of manufacture. Scoring contests are often held to determine the ability of contestants to estimate and evaluate the attributes of cheese, and other dairy products. Judging of cheese is therefore important in the fields of commerce, research, and education.

### Grading of Cheese

Grading of cheese is an essential step in orderly marketing of cheese. Well established grades identify quality as the cheese moves from the factory into commercial channels. The first sale of cheese in the primary market determines the returns for the care exercised by farmers in producing milk and by the makers in turning the milk into cheese. Adequate remuneration for the grade of cheese produced is the basis of any financially sound and effective quality improvement effort.

Grades might be placed upon cured cheese when it moves into the retail trade; this would be very desirable for the consumers' information. Such grades would indicate the quality attained in curing. At present the grades placed on cheese when it is first sold are the only ones used. The United States Depart ment of Agriculture (1943) announced tentative grading standards on April 29, 1943 that contained specifications for grades applicable to cheese of different ages. These standards indicate the essential differences between fresh cheese, medium cured, and cured cheese. Such standards can be applied for consumer use.

Fryhofer and Potts (1923) explained the importance of national standards in grading cheese. They stated that such standards would promote production of better cheese of more uniform quality because producers, dealers and consumers would be able to identify the extent of defects, and better grades would command higher prices. They hoped that national grades would facilitate freer contracting between widely separated markets by providing a uniform basis for determining quality.

Grades established by the Wisconsin Department of Agriculture (1941) for Cheddar cheese are reproduced here because they are brief, simple and have been generally used and widely accepted in the cheese industry:

### Wisconsin State Brand

"1. *Flavor.* Flavor and taste shall be practically clean, with nothing objectionable. Cheese of this grade must have a flavor clean enough to suit any of our markets, not merely a flavor that will get by in certain markets.

"2. *Body and Texture.* Cheese must have a good body; must be close or medium close but not open. Scattered shot holes are permitted. Must show meatiness and smoothness according to age. Cheese must not be corky, crumbly, mealy, acid, weak, pasty, gassy, or otherwise defective.

"3. *Color.* May be uncolored or of any degree of color recognized in the markets. Must be uniform. Color must not be dull or faded.

"4. *Finish and Appearance.* Cheese must be well dressed, well shaped, and practically uniform in size. Surfaces must be well closed, sound, smooth, clean, free from checks, and practically free from mold.

"5. *Moisture.* Cheese of this grade shall have not more than 38% of moisture, with an allowance or tolerance of not to exceed 1% in excess, so that in no case shall the moisture content of said cheese exceed 39%."

**Wisconsin Junior**

"1. *Flavor.* Flavor and taste may be slightly defective.

"2. *Body and Texture.* Body and texture may be slightly defective; may be medium open or slightly gassy.

"3. *Color.* May be uncolored or of any degree of color recognized in the markets. May be slightly defective.

"4. *Finish and Appearance.* May have slight defects in shape and in finish; must be practically uniform in size; surfaces may have slight defects but must be reasonably clean.

"5. *Moisture.* Cheese of this grade may have not more than 39% of moisture with an allowance or tolerance of not to exceed 1%, so that in no case shall the moisture content of said cheese exceed 40%."

**Undergrade**

"Cheese of inferior quality or finish, having any pronounced inferior or objectionable flavor or taste; which is corky, crumbly, short, mealy, acid, weak, pasty, gassy or otherwise seriously defective; and cheese uneven in color, mottled or too highly colored and faulty in shape, finish and appearance, with surfaces which are defective, and cheese which is inferior to Wisconsin Junior, shall be considered Undergrade."

The tentative grades of the United States Department of Agriculture (1943) include the following divisions: (1) U. S. Grade AA, or U. S. Fancy; (2) U. S. Grade A, or U. S. No. 1; (3) U. S. Grade B, or U. S. No. 2; (4) U. S. Grade C, or U. S. Undergrade; (5) No Grade. General specifications for cheese of all ages are given for each grade; additional specifications that are applicable to cheese of different ages are included for each grade. The general specifications for cheese of all ages for the various grades are:

**U. S. Grade AA or U. S. Fancy, general specifications—all ages**

"*Flavor.* It shall be free from undesirable flavors.

"*Body and Texture.* The plug should have the appearance of being solid, compact, and close boring. It may have a few small mechanical openings but no large openings. It shall be free from sweet holes, yeast holes, or gas holes of any kind.

"*Color.* May be uncolored or medium colored but must be uniform and translucent.

"*Finish and Appearance.* Shall be free from cracks in the rind, soft spots, rind rot, scaly paraffin, and other surface defects which may cause deterioration of the cheese. The bandage shall be evenly placed on both ends of the cheese and free from unnecessary overlapping and wrinkles. The cheese must not be lopsided and must be free from any huffing and high edges. The starch circles may be left on at time of paraffining or at that time may be removed. The cheese must have a good coating of paraffin or wax that adheres firmly to the surface of the cheese. The cheese shall be of uniform weight."

### U. S. Grade A or U. S. No. 1, general specifications—all ages

"*Flavor.* It shall be free from undesirable flavors. It may have slight regional or seasonable feed flavors.

"*Body and Texture.* The plug when drawn should have the appearance of being solid and compact, close or medium close. It may have a few mechanical openings but these should not be large and connecting. It may have an occasional sweet or Swiss hole, but not more than two on a plug pulled by a regular size cheese trier. It shall be free from other gas or yeast holes.

"*Color.* May be uncolored or medium colored but must be uniform and translucent; may be slightly seamy.

"*Finish and Appearance.* Shall be free from cracks in the rind, soft spots, rind rot, scaly paraffin, and other surface defects that may cause deterioration of the cheese. The bandage shall be fairly evenly placed on both ends of the cheese and practically free from unnecessary overlapping and wrinkles. The cheese must not be more than slightly lopsided, practically free from high edges, and free from any huffing. The starch circles may be left on at time of paraffining or at that time may be removed. The cheese must have a good coating of paraffin or wax that adheres to the surface of the cheese. The cheese shall be of uniform weight."

### U. S. Grade B or U. S. No. 2, general specifications—all ages

"*Flavor.* It shall be free from strong, undesirable flavors.

"*Body and Texture.* May be loose and open. May have numerous sweet holes, or scattered gas holes, or yeast holes.

"*Color.* May be uncolored, medium, or high colored. May be seamy, slightly acid cut, or faded, slightly wavy, or slightly mottled.

"*Finish and Appearance.* May have a rough or unattractive appearance. May have scaly paraffin. May be slightly huffed. It may be lopsided but not to the extent the lid will not fit squarely on the box. The rind must be solid and free from soft spots.

rind rot, and cracks or openings of any kind. The bandage can be uneven, overlapped, or wrinkled, but must not be burst or torn. There must be no indication that mold has entered the cheese. The starch circles may be left on at time of paraffining or at that time may be removed."

### U. S. Grade C or U. S. Undergrade, general specifications—all ages

"*Flavor.* There shall be no offensive flavors.

"*Body and Texture.* May be loose and open. May have sweet holes, yeast holes, or gas holes.

"*Color.* May be uncolored, medium, or high colored. May be acid cut or faded, wavy, seamy, or mottled. It shall not be wavy or mottled to the extent that it is unpalatable or repulsive.

"*Finish and Appearance.* May have a rough, unattractive appearance. May have scaly paraffin, may be huffed or lopsided, may have a soiled surface but shall be reasonably free from surface mold. The rind must be practically free from rind rot, cracks, or openings. There must be no indication of mold entering the cheese."

### No Grade Cheese

"Cheese of any age or having the following defects which is below the requirements of U. S. Grade C, or Undergrade, shall be classified as "no grade" cheese.

"*Flavor.* Any offensive flavor such as putrid, kerosene, gasoline, fly spray, oil or paint, or such flavors as rancid, fishy, chemical, sour, fermented, fruity, onion, or obnoxious weed flavor, or other undesirable flavors to the extent that they are offensive.

"*Body and Texture.* Weak, to the extent a normal plug cannot be drawn from the cheese.

"*Color.* Discoloration caused by foreign material or by bacterial action. Or if the color is such that the cheese is unpalatable.

"*Finish and Appearance.* Excessive cracks or openings in rind. Any indication of mold growth in the interior of the cheese. Soft wet rind or rind rot. Cheese mites if there are any openings in the rind.

"Cheese marked "no grade" may or may not be edible."

TABLE 18:1. CHEDDAR CHEESE SCORE CARD OF THE AMERICAN DAIRY SCIENCE ASSOCIATION
(after Trout, 1943)

| *Perfect Score* | *Score* | *Common criticisms* | | |
|---|---|---|---|---|
| Flavor—45 | | Acidy<br>Bitter<br>Cowy<br>Feed<br>Fermented | Flat<br>Fruity<br>Heated<br>Moldy<br>Rancid | Unclean<br>Weedy<br>Yeasty |
| Body and Texture—30 | | Corky<br>Crumbly<br>Curdy<br>Flaky<br>Gassy | Mealy<br>Open<br>Pasty<br>Spongy<br>Sweet curd holes | Weak<br>Yeast holes |
| Finish—15 | | Cracked rind<br>Huffed<br>Light spots<br>Moldy<br>Rot spots | Scaly paraffin<br>Soiled<br>Uneven surfaces<br>Wrinkled bandage | |
| Color—10 | | Acid-cut<br>Mottled | Seamy<br>Wavy | |
| Total—100 | | | | |

## SCORING OF CHEESE

Scoring of cheese, unlike grading, has no wide commercial application. Its value for educational and research purposes, however, cannot be questioned. The American Dairy Science Association has sponsored intercollegiate students' dairy products judging contests since 1916. Since 1930 the contests have been sponsored jointly by this association and the Dairy Industries Supply Association, Inc. Trout, et al. (1939), in discussing the history of these contests, pointed out that they have been valuable to both students and coaches alike; they have contributed to the attainment of standards and ideals of perfection for cheese and the other products judged.

TABLE 18:2. NORMAL RANGE OF SCORES FOR CHEDDAR CHEESE
(after Trout, 1943)

| *Attribute* | *No criticism* | *Criticized* | *Normal range* * |
|---|---|---|---|
| Flavor | 40 —45 | 39.5 or less | 35—42 |
| Body and Texture | 29.5—30 | 29 or less | 26—29.5 |
| Finish | 15 | 14.5 or less | 14—15 |
| Color | 10 | 9.5 or less | 9—10 |

* This should not be interpreted to mean that all cheese is scored within this range.

TABLE 18:3. AVERAGE FLAVOR SCORE OF CHEESE WITH CERTAIN INTENSITIES OF OFF-FLAVOR
(Trout, et al., 1942)

| *Flavor Criticism* | *Average score for cheese flavor when the intensity of the defect was:* | | |
|---|---|---|---|
| | *Slight* | *Distinct* | *Strong* |
| Acidy | 38.5 | 37.3 | 35.8 |
| Bitter | 38.5 | 37.2 | 35.6 |
| Cowy | 37.8 | 36.7 | 35.3 |
| Feed | 38.7 | 37.6 | 36.5 |
| Fermented | 37.3 | 36.2 | 35.0 |
| Flat | 39.5 | 38.9 | 38.4 |
| Fruity | 37.8 | 36.7 | 35.5 |
| Heated | 38.9 | 37.8 | 37.0 |
| Moldy | 37.2 | 35.9 | 35.1 |
| Rancid | 36.8 | 35.7 | 34.8 |
| Unclean | 38.1 | 36.9 | 35.1 |
| Weedy | 37.9 | 36.8 | 35.3 |
| Yeasty | 37.1 | 36.0 | 35.0 |

The score cards used in these contests are probably better known in the United States today than any others. From 1916 to 1938, inclusive, 22 contests were held. A total of 861 contestants actually participated. The number of men trained in scoring, but not successful in entering the national contests, would probably be several times this total.

TABLE 18:4. SCORING BODY AND TEXTURE IN CHEDDAR CHEESE
(Perfect score—30)

| *Body and texture criticisms* | *Approximate cut in score when the degree of the defect is:* | | |
|---|---|---|---|
| | *Slight* | *Distinct* | *Pronounced* |
| *Body defect* | | | |
| Corky | 1.0 | 1.5 | 3 |
| Crumbly | 1.0 | 1.5 | 4 |
| Curdy* | 1.0 | 1.5 | 2 |
| Flaky | 1.0 | 1.5 | 3 |
| Mealy | 1.0 | 1.5 | 3 |
| Pasty | 1.0 | 1.5 | 4 |
| Weak | 1.0 | 1.5 | 3 |
| *Texture defect* | | | |
| Gassy | 1.5 | 2.0 | 4 |
| Open | 1.0 | 1.5 | 3 |
| Spongy | 1.5 | 2.0 | 4 |
| Sweet curd holes | 1.0 | 1.5 | 3 |
| Yeast holes | 1.5 | 2.0 | 4 |

* Curdiness can be criticized only when the condition is unnatural for cheese of that age. It is not a defect in fresh cheese.

TABLE 18:5. SCORING FINISH OF CHEDDAR CHEESE
(Perfect score—15)

| *Finish criticisms* | *Approximate cut in score when the degree of the defect is:* | | |
|---|---|---|---|
| | *Slight* | *Distinct* | *Pronounced* |
| Cracked rind * | 0.5 | 1.0 | 2.0 |
| Dirty | 0 | 0.25 | 1.0 |
| Greasy | 0 | 0.25 | 1.0 |
| Huffed | 0.25 | 0.5 | 2.0 |
| Loose Paraffin ** | 0.25 | 0.5 | 1.0 |
| Moldy | 0 | 0.25 | 1.0 |
| Rind rot | 0.5 | 1.0 | 2.0 |
| Uneven surfaces | 0 | 0.25 | 0.5 |
| Wrinkled bandage | 0 | 0.25 | 0.5 |

* Also called "checked" rind.
** Also called "scaly" paraffin.

The American Dairy Science Association (1920) adopted an official score card which assigned numerical values to the attributes of the cheese. This score card, slightly modified, has been incorporated in the Rules of Students' National Contest in Judging Dairy Products, 1942, and is shown with common terms of criticism in table 18:1. Table 18:2 shows the normal range of scores for the various attributes of the cheese.

It is common practice in scoring cheese to use less than the 15 allowable points for flavor, even when no defects can be detected. This is due in part to the fact that, unlike other dairy products, Cheddar cheese develops desirable and characteristic flavors in ripening. Marquardt (1939) suggested that these desirable flavors developed in normal ripening should be evaluated separately. The idea has merit.

The best judges have the greatest ability to identify the

TABLE 18:6. SCORING COLOR OF CHEDDAR CHEESE
(Perfect score—10)

| *Color Criticisms* | *Approximate cut in score when the degree of the defect is:* | | |
|---|---|---|---|
| | *Slight* | *Distinct* | *Pronounced* |
| Acid-cut | 0 | 0.25 | 1.0 |
| Bleached | 0.25 | 0.50 | 1.0 |
| Mottled | 0 | 0.25 | 1.0 |
| Seamy | 0 | 0.25 | 0.5 |
| Wavy | 0 | 0.25 | 0.5 |
| White specks | 0 | 0 | 0 |

faults in cheese according to Trout (1939) and Trout, et al. (1940). Trout and his coworkers (1942) asked 50 trained judges to select from their number a panel of judges to evaluate intensities of off-flavors. The results of the efforts of the selected judges are shown in table 18:3. The numerical scores suggested in tables 18:3, 18:4, 18:5 and 18:6 are useful for standardizing judging of cheese flavor for industrial, educational and research purposes.

## TECHNIQUES OF JUDGING CHEDDAR CHEESE

The manner of judging Cheddar cheese has a direct influence on the ability of the judge to detect and evaluate the desirable and undesirable attributes of the cheese. These techniques can be learned, but the judge himself must first of all have ability to undertake this task. Josephson (1946) pointed out that individuals vary widely in their abilities to detect and evaluate flavor defects. He studied five trained observers, three of whom had judged dairy products for 15 to 25 years. Some of them were more sensitive to certain flavors than others. An especially sensitive reaction to one flavor was frequently associated in the same individual with marked insensitiveness to another. Under controlled conditions one judge consistently called a flavor "pronounced," the second judge, "slight," and the third detected no off-flavor. Judging panels should be selected carefully. The training of student judges should begin with tests to determine their ability to detect the sensations of sweet, salt, sour, and bitter in dilute solutions. Trout and Sharp (1937) suggested a procedure for determining the reliability of flavor judgments which depend primarily on the sense of smell.

His surroundings must be favorable for the cheese judge to do his best work. Judging is too frequently done under unfavorable conditions. Suitable surroundings for judging can be described in terms of space, light, odors, temperature, distractions, and sanitary facilities.

The *space* allotted to the judging work should be adequate to accommodate the judge or judges and their helpers. Commercial operations require space for smooth and rapid movement of stock before the judge. Educational judging requires space for demonstrations and individual and independent work by students.

The *light* for judging must be adequate for the examination of the cheese, its color, its markings, and finally for the record keeping that is a necessary part of commercial or educational work. Daylight is ideal for judging if there is enough of it. Daylight lamps are preferred when natural light is not available. Inadequate light and colored light introduce an unnecessary element of error and place a needless strain upon the judge.

*Odors* in the air in the place of judging may be particularly confusing. The odors of a hot paraffin tank, tobacco smoke, smoke from a nearby boiler or railroad, fresh paint, disinfectants, insect sprays, and dust are all common hazards of judging and are not infrequently encountered under conditions of commercial grading. Scented soaps, shaving lotions, and the like can be highly objectionable. Such odors tend to conceal cheese flavors, fatigue the sense of smell, and deaden the sensitivity of the judge to certain odor characteristics.

The *temperature* of the room or place in which the judging occurs is important. The judge should be comfortably warm, a condition impossible to attain on a cold receiving platform or in a refrigerator. Cold temperatures make it more difficult to detect odors. The cheese judge depends largely on the warmth of his fingers to warm cold cheese before he can hope to smell all the odors present in it. This is impossible to do for any extended period of time in the cold. The only alternative is to warm the cheese by chewing it, a procedure which may lead to other errors of judgment. Furthermore, the temperature of the cheese itself can be too cold to permit accurate judging. Arbuckle, Edmondson, and Mull (1940) found that cheese of low quality received a lower flavor score when scored at temperatures of 60° or 70° F. than at 40° to 50° F. High quality cheese, on the other hand, scored better at the higher temperatures. As temperatures of the cheese increased from 40° to 70°F., the score on flavor varied as much as 2.5 points. As would be expected, the body characteristics changed considerably with changing temperatures at judging.

*Sanitary facilities* for judging are important. There should be a convenient place to wash and dry hands. It is necessary to handle cheese, cheese boxes, and cheese plugs. The judge's hands must be clean and free from foreign odors and the odors of cheese which has already been examined.

Cleaning of the trier between samples is essential for careful work. This is usually easily accomplished with a stainless steel trier by polishing it with clean paper toweling, clean cloth or toilet tissue. Occasionally washing may be necessary between samples. Steel triers may become particularly offensive in the course of judging acid and sticky cheese. Such triers should be washed often, if they must be used at all.

There should be a place to dispose of waste bits of cheese, soiled paper toweling, and the like. Throwing these waste materials behind stacks of boxes, into the box with the cheese, on the floor, or out of doors "for the birds," creates a nuisance by attracting dogs, cats, and rodents, and by providing breeding conditions for flies, skippers, cheese mites, ants, and other insect pests.

If the cheese is tasted, it must be cleaned out of the mouth before judging the next sample. A drinking fountain and a special sink with continuously running water should be provided in judging rooms for those who taste cheese and then spit it out. A metal container may be used to collect waste bits of cheese, soiled toweling, or tissue. Such containers must be emptied and cleaned daily.

*Distractions*, which take the attention of the judge, detract from the accuracy of sensing and evaluating the attributes of the cheese. Common distractions are conversation, comments of others concerning the cheese, crowding around or bumping the grader, and duties conflicting with the responsibility of judging. The grader is often the logical man to carry managerial responsibilities. Proper organization of his work will make it possible for him to arrange these duties so that when he is actually grading cheese he can give that work his undivided attention.

## SAMPLING THE CHEESE

A sample of cheese for judging is obtained with a cheese trier. Stainless steel triers should be used for careful grading work because they give off no metallic flavor or odor. Many experienced judges continue to use the well-worn steel triers they have cherished for many years; by doing so, a needless handicap is often imposed upon the senses of taste and smell for the sake of the information that can be gained concerning the cutting properties, appearance, and body of the cheese as they are revealed by the use of the old, familiar trier.

Triers used for cheese vary in size. They are commonly long enough to pull a five-inch plug. The plug, at the rind end, is usually about eleven-sixteenths of an inch in diameter and, at the bottom, approximately nine-sixteenths. Some triers are made small enough to pull a plug only one-quarter inch in diameter, others may cut a plug over three-fourths of an inch in diameter.

They vary in length from three or four inches up to approximately eighteen inches. These extremes are not commonly used for judging Cheddar cheese, although the larger triers have some application in sampling cheese for analytical purposes.

The clean, polished trier is inserted into one of the flat ends of the cheese at an angle of about 45°. The point of plugging is usually about one third to one half of the distance from the circumference to the center of the cheese. The trier is inserted to the depth of its cutting edge and is then rotated a little more than half of a circle so that a cylinder of cheese, the plug, is held in the trier and attached, if at all, only at the bottom end to the cheese itself. The trier is then withdrawn. The normal taper of a good trier usually furnishes enough grip to hold the entire plug of a normal cheese during this operation. When a good trier cannot pull a whole plug from a cheese, either body or texture is probably faulty.

## Examination of the Plug of Cheese

The examination of the plug of cheese follows a definite routine. The judge has in mind the characteristics of the ideal cheese in terms of flavor, body, texture and color. He attempts to evaluate the sample before him in terms related to this ideal. It is important that factors affecting the detection of flavor, the body, and appearance of the cheese should be kept as constant as possible during the judging routine.

When the plug is drawn the judge smells of it immediately to detect volatile odors which may quickly be lost. It should have a clean, pleasant aroma with nothing objectionable.

Next the appearance of the plug is noted. Its texture and color can be criticized best at this instant before the plug is broken. The plug of cheese should show few small openings or none at all; the surface should be smoothly cut; and the color should be characteristic and uniform.

The plug is then lifted or rolled out of the trier with the fingers. It should come out in one piece.

The plug is held in the thumbs and fingers of both hands and bent until it breaks. The resistance it offers, the amount of bending before breaking, the tendency to break slowly or sharply, and the appearance of the broken surfaces are significant. A distinct bend before breaking, a slow break, and a flint-like appearance of the broken surfaces are indications of satisfactory body.

After the plug has been broken, the judge interrupts his examination of the cheese to replace at least one inch of the rind end of the plug into the hole from which it was taken. The closure should be flush with the surface of the cheese, and the scar may be sealed later with wax or paraffin.

The body of the cheese is examined next for firmness by crushing a one-inch piece of plug between the thumb and first two fingers; the force required indicates the firmness of the cheese. The pressure necessary to crush a one-inch piece of plug which is roughly five-eighths of an inch in diameter approximates seven pounds for cured cheese of good quality. If the cheese is fresh and curdy, it will be slightly firmer than the ideal aged cheese.

The piece of plug is then kneaded like a miniature loaf of bread to test for smoothness of body. This requires ten to fifteen seconds and approximately ten squeezes between the thumb and first two fingers, if the cheese is at 60° F., the ideal temperature for judging. This kneading ends with the crushed plug formed into a ball of curd. Crumbling of the plug is normal only in fresh cheese; this type of crumbling is the curdiness which usually disappears within 30 days at curing temperatures. In one final motion, the ball of curd is pressed and firmly rubbed, or stroked, between the thumb and first two fingers. In this single stroking motion, the thumb spreads the ball of curd from the tips toward the base of the first two fingers. The fingers are slightly bent at the beginning of this motion and should remain slightly flexed. If they are straightened out, the layer of curd formed by the stroking motion is usually broken and may give a deceiving appearance of mealy body. The cheese layer on the fingers should have the smooth waxiness of cold butter.

Prolonged kneading, working, and rubbing of the cheese causes fat to separate from it; this makes the body disintegrate, and gives a false impression of its true consistency.

The judge notes the appearance and smoothness of the cheese in his fingers and immediately smells the mass by holding the thin layer close to both nostrils and sniffing vigorously two or three times, or by inhaling a full breath of air in about two seconds. The odor should be clean, pleasing, and characteristic for the age of the cheese. The ideal odor can only be identified and memorized by working with a competent judge. When the aroma of the sample cannot be classified and evaluated by the first smelling, the mass of cheese should be kneaded for a few seconds and the sniffing repeated.

A fresh piece of cheese may be worked for further study. A careful judge uses approximately the same amount of cheese; he kneads it to the same consistency and temperature as were used in examining the first sample.

Tasting of cheese is carefully avoided by some judges who state that it dulls their senses of taste and smell. Other judges always taste cheese as part of their judging routine. Tasting of cheese is usually done only after the odor has been observed by smelling. The sensations of sweet, salt, sour, and bitter are detected only by the taste buds that are located chiefly on the surface of the tongue. The taste buds are not uniformly distributed so that enough cheese must be taken into the mouth to permit full utilization of the sensitive surfaces. The tip, edges, and the back part of the tongue are sensitive to all four sensations; the top of the tongue, especially toward the front, is relatively insensitive to bitterness and saltiness. The dominant taste of Cheddar cheese is mildly salty. The acidity found in normal Cheddar cheese does not impart a sour flavor that is so classified by a cheese judge.

Tasting of cheese is a more leisurely procedure than smelling. Placing the cheese in the mouth is not only essential to detect the sensations of sweet, salt, sour, and bitter, but it also contributes to the judge's information concerning the odor, consistency and smoothness of the cheese. The cheese is warmed to a uniform temperature in the mouth, and the odors are naturally wafted, or are pumped by the motions of the tongue, into the upper regions of the nasal passages where the olfactory cells are situated. Tasting eliminates the possibility of contamination or confusion of odors which may come from the fingers, but it introduces the possible error of incomplete removal from the mouth of all traces of former samples. Different samples are usually tasted at intervals of not less than one minute; the intervals may be as much as five minutes when very strong flavors are found. Rinsing the mouth with warm water is helpful in shortening the intervals between tasting of samples.

The feeling of cheese in the mouth during tasting contributes to the judge's evaluation of the quality. The cheese that is well broken down disperses in the mouth giving a sensation somewhat resembling that of rich cream. Fresh cheese is elastic and disperses in the mouth only with chewing and then it leaves a roughness characteristic of lack of age. Firmness of the cheese is indicated by the resistance it offers to biting and chewing. Cheese which is fully aged often gives a slight tingling or peppery sensation in the mouth and throat. In cheese that is over-cured these pleasant sensations become biting and unpleasant. They are associated with pungent aromas which closely resemble ammonia.

The judge scores or grades the cheese as soon as the routine of the examination has been completed; some judges even prefer to record the score on each characteristic of the cheese as it is examined. There should be no intervals or interruptions between the examination and the recording of the decision. After the decision has been recorded, the judge cleans his trier, wipes or washes his hands, and clears or rinses his mouth, so that no trace of the cheese he has judged will contaminate the next sample.

## THE ATTRIBUTES OF CHEDDAR CHEESE

The characteristics of cheese are described by judges to indicate the value of the cheese, the stage of its ripening development, and the purposes for which it is suited. Specific terms are used to describe its desirable qualities and faults. The language of cheese judges in commercial fields has not been standardized; new terms appear, others fall into disuse, some lose their original meaning. Individuals coin terms to indicate a shade of meaning not provided by the common descriptive terms. The results are picturesque but sometimes confusing. The work of the committees on judging of the American Dairy Science Association has had a unifying influence; hundreds of college students have learned the standardized terms of the Association. These men are now using these terms as they engage in professional work. An attempt is made in the following paragraphs to define commonly used terms and to group those which seem to be synonymous or at least so similar that distinction would seem to be an unnecessary refinement in terminology.

## TERMS DESCRIBING AGE OF CHEESE

The qualities of cheese change with age. Judges allow for age when considering the quality classification of the cheese. Cheese can be of superior quality even when it is very young and not yet ready for use.

**Fresh.** This term indicates newly made cheese which has the odor, taste, and curdy body of very young cheese; the term is usually applicable for about 30 days.

**Mild.** Mild cheese is partly cured. The body is free of all curdiness and the characteristic cheese flavor is beginning to be apparent.

**Aged.** Aged cheese is fully cured. The characteristic cheese flavor is distinct although it may vary in intensity depending upon the nature of the cheese and the curing process to which it has been subjected. Body characteristics of such cheese may or may not show the effects of normal losses of moisture.

## THE FLAVOR OF IDEAL CHEDDAR CHEESE

Ideal Cheddar cheese has a clean, pleasing aroma that is characteristic of the age of the cheese. It is mildly salty in taste and when fully aged, it causes a pleasant tingling sensation within the mouth. After the cheese is swallowed, there is a pleasant after-taste resembling the flavor of sweet nuts.

## TERMS DESCRIBING FLAVOR

In preparing this alphabetically arranged list of terms used in describing flavor the following sources of information have been most useful: Fryhofer and Potts (1923), Phillips and Abbott (1932), Downs (1937), and U. S. Department of Agriculture (1943).

**Acid, acidy:** An odor which suggests sourness, the odor of starter; the taste may or may not be sour.

**Aged:** The odor and taste of fully cured cheese.

**Barny:** An odor resembling that of the cow barn.

**Bitter:** A taste similar to that of quinine.

**Clean:** Odor and taste are free of objectionable defects.

**Cooked:** An odor associated with the use of pasteurized milk for cheese.

**Cowy:** An odor, usually faint, resembling cow barn odors.

**Feed:** An odor of a strong food eaten by cows; examples are: silage, alfalfa, cabbage, turnips.

**Fermented:** The odor of an unclean whey tank; the odor of an alcoholic fermentation.

**Fishy:** The odor of fish; it sometimes appears in over-cured cheese.

**Flat:** Lacking in cheese flavor; flat is also used to indicate lack of salt.

**Foreign:** Odors attributable to contamination of milk or curd with such materials as fly spray, gasoline, kerosene, oil, or paint.

**Fresh:** The odor and taste of newly made cheese.

**Frosted feed:** The odor of frozen feeds commonly eaten by the cow in late fall and winter.

**Fruity:** A sweet, aromatic, fragrant odor which sometimes resembles certain fruits; the odor of an alcoholic fermentation.

**Gassy:** The odor which accompanies a gassy fermentation in milk or curd.

**Heated:** This term is rarely used; it is defined by Fryhofer and Potts (1923) as a flavor common in cheese during the summer months, and by Downs (1937) as a flavor resembling that of heated fat in over-heated milk.

**High:** A delicate, pleasing aroma which disappears quickly.

**High-acid:** A clean, sharp, acid aroma and taste.

**Highly pleasing:** A particularly fine, clean, fully developed aroma and taste.

**Hydrogen sulfide:** The odor of hydrogen sulfide; the odor of sulfur water.

**Lacking:** Absence of characteristic Cheddar cheese flavor.

**Low:** Very little cheese flavor.

**Metallic:** An odor resembling that produced by the action of a mild acid on iron.

**Mild:** The odor and taste of partially cured cheese; the Cheddar cheese flavor is definite but not intense.

**Moldy:** The musty or pungent odor caused by the growth of mold in or on the cheese.

**Nutty:** The odor and taste resembling that of sweet, fresh nutmeats.

**Offensive:** The term used to classify odors and tastes that are distasteful, repugnant, or repellent.

**Off:** An undesirable taste or odor not characteristic of normal cheese and too faint to describe in other terms.

**Onion:** An odor resembling that of onions.

**Oxidized:** An odor resembling that of stale tallow.

**Putrid:** The odor of putrefaction.

**Quick:** A delicate, pleasing aroma which disappears quickly

**Rancid:** The odor of butyric acid.

**Sharp:** The strong, pleasing, characteristic, Cheddar cheese flavor found in fully aged cheese.

**Smothered:** The accumulated odor in Cheddar cheese which has been cured in a sealed container or wrapper, or which has been cured too rapidly to permit normal escape of carbon dioxide. The flavor is usually slightly acid, slightly fermented and has traces of ammonia and hydrogen sulfide when the cheese is fully cured. The odor fades rapidly but does not entirely disappear when the cheese is cut and exposed to air.

**Sour:** The pronounced odor and taste of a cheese that is excessively acid.

**Stable:** An odor resembling that of the cow barn.

**Tainted:** Odors that are mildly offensive but which cannot be identified.

**Tallowy:** The odor resembling that of tallow.

**Unclean:** A term used to describe odors and tastes that are mildly offensive but which cannot be identified; they may leave an unpleasant aftertaste; they may suggest unclean conditions of milk production or of cheese manufacturing.

**Utensil:** The odor associated with that of carelessly cleaned milking machines, milk cans, and milk handling equipment.

**Weedy:** Odors or tastes of weeds eaten by cows; examples are onions, leeks, and bitterweed.

**Whey taint:** The odor resembling that of sour, fermented whey; the odor of an alcoholic fermentation.

**Yeasty:** The odor resembling that of a yeasty fermentation such as that of fresh bread dough.

## The Body of Ideal Cheddar Cheese

The body of ideal Cheddar cheese is slightly elastic; it breaks slowly when the plug is bent; the broken ends of the plug show small grooves or lines that are roughly parallel and resemble the striations of broken flint; it is firm but not hard when crushed in the fingers; and it is smooth and waxy in consistency when kneaded momentarily and then rubbed between the fingers.

### Terms Describing Body

The terms commonly used in describing body of Cheddar cheese are arranged alphabetically in the following list. Helpful sources of information in formulating these definitions were: Downs (1937), Fryhofer and Potts (1923), Phillips and Abbott (1932), and U. S. Department of Agriculture (1943).

**Corky:** A consistency like cork; firm, hard, tough, and difficult to crush and knead into a plastic mass.

**Crumbly:** An easily broken, friable consistency which is evident when the cheese is plugged, sliced, or kneaded in the fingers.

**Curdy:** The consistency of newly made cheese in which the elastic properties of the cheese curd still persist.

**Dry:** A consistency that is too firm and hard; such cheese is difficult to crush and knead into a plastic mass.

**Firm:** A consistency that requires more than normal pressure to crush the cheese.

**Flaky:** Lack of cohesion; improper knitting together of the curd particles; fractures of plug show smooth, non-striated, glistening surfaces.

**Gritty:** Consistency that is rough, coarse, or mealy when the cheese is kneaded and rubbed between the fingers.

**Mealy:** A consistency that is rough or coarse when the cheese is kneaded and rubbed between the fingers.

**Meaty:** A firm, solid, substantial consistency.

**Pasty:** A soft, weak consistency which requires less than normal pressure to crush the cheese; when kneaded in the fingers, the cheese becomes sticky, salvy or smeary.

**Rubbery:** An elastic consistency; curdy; plug bends readily without breaking.

**Salvy:** Soft, weak consistency; excessively smooth and sticky.

**Short:** Lack of cohesion and elasticity; the plug tends to break without bending; the cheese crumbles in the fingers when crushed.

**Silky:** Smoothness evident when the cheese is kneaded and rubbed between the fingers.

**Smooth:** A feeling resembling that of cold butter or soft wax observed when the cheese is kneaded and rubbed between the fingers; lacking in roughness, mealiness, and grittiness.

**Soft:** Weak, pasty, smooth, sticky consistency.

**Solid:** Firm, meaty consistency.

**Spongy:** Excessively elastic, weak body that is usually caused by many holes or cavities in the cheese.

**Sticky:** Weak, pasty consistency tending to stick to the fingers when crushed and kneaded.

**Stiff:** Consistency lacking in plasticity; difficult to crush and knead into a plastic mass; hard, tough, overly firm.

**Waxy:** Firm, smooth consistency resembling that of soft wax or cold butter when the cheese is crushed and kneaded in the fingers.

**Weak:** Consistency requiring less than normal pressure to crush and knead the cheese in the fingers.

### THE TEXTURE OF IDEAL CHEDDAR CHEESE

The texture of ideal cheese is compact, continuous, and homogenous: it is free from openings, holes, breaks, cracks, or fissures.

### TERMS DESCRIBING TEXTURE

**Candle:** As free of openings as a candle.

**Close:** Practically free of all openings.

**Compact:** Free of openings.

**Crack:** Thin opening in the cheese; a narrow break usually between particles of curd.

**Fish-eye:** Elliptical opening or short fissure, usually small, and attributed to yeasty fermentations.

**Fissure:** A narrow opening formed by the separation of the curd particles.

**Gas holes:** Openings in the cheese that are commonly small and approximately round; holes formed by gas-producing organisms.

**Loose:** Numerous mechanical openings which make it difficult to draw a continuous plug.

**Mechanical openings:** Spaces of irregular size and shape in the cheese formed by the joining of the curd particles; openings not primarily caused by gas formation.

**Open:** Numerous spaces or holes in the cheese; numerous gas holes or mechanical openings or both.

**Pinholes:** Very small, rounded holes caused by the formation of gas-producing organisms.

**Porous:** Numerous spaces or holes in the cheese; numerous mechanical openings.

**Shot holes:** Sweet holes about one-eighth inch in diameter.

**Sweet holes, sweet curd holes, sweet gas holes:** Rounded openings with glossy interiors.

**Swiss holes:** Sweet holes of unusually large size that resemble the eyes of Swiss cheese.

**Yeast holes:** Short fissures or elliptical openings often attributed to the formation of gas by yeasty fermentations; yeast holes are sometimes called "fish eyes."

## THE COLOR OF IDEAL CHEDDAR CHEESE

The color of ideal Cheddar cheese is uniform. When it is not artificially colored, it is light amber to ivory, depending on the season of the year and feed of the cow. Colored cheese normally varies from golden yellow to cadmium orange.

## TERMS DESCRIBING COLOR OF CHEDDAR CHEESE

**Acid-cut:** The bleaching of the normal cheese color associated with the presence of excessive acidity in the cheese.

**Bleached:** Another term for acid-cut.

**Faded:** Another term for acid-cut.

**High:** Shades of color approximating cadmium orange.

**Light:** Shades of color approximating ivory.

**Mottled:** Areas with varying intensities or shades of color.

**Red spots, rusty spots:** Small spots scattered through the cheese and having the appearance of iron rust.

**Seamy:** The cut surface of the cheese shows white lines surrounding the cross section of each curd particle.

**Streaked:** Color is not uniform and appears as irregularly arranged stripes or narrow bands.

**Translucent:** The plug of cheese transmits light when held between the eye and a bright source of illumination.

**Uniform:** Evenly colored; without variations; homogeneous.

**Wavy:** Irregular distribution of color that is apparent in the form of streaks or waves.

**White specks:** Small specks of white distributed throughout the cheese; they are relatively insoluble and range in size from the scarcely discernible to that of small peas.

## THE APPEARANCE OR FINISH OF IDEAL CHEDDAR CHEESE

The exterior of ideal Cheddar cheese has a smooth, unbroken rind and a neat, clean, attractive appearance.

## TERMS DESCRIBING FINISH OR APPEARANCE OF CHEDDAR CHEESE

**Checks:** Small cracks or crevices in the rind.

**Cracks:** Openings, flaws, fissures, or crevices in the rind of the cheese.

**Dirty:** Soiled surfaces.

**Greasy:** Surfaces covered with fatty substances.

**High edges:** Narrow bands of curd extruded during pressing between the side of the hoop and the follower.

**Huffed:** Swelling or bloating of cheese associated with excessive gas formation within the cheese.

**Loose paraffin:** Paraffin or wax failing to adhere tightly to the surface of the cheese.

**Lopsided:** Cheese that is higher on one side than on the other; cheese that leans away from the vertical axis of the ideal cylindrical or rectangular form.

**Moldy:** The appearance of mold on the surface of the cheese, either on the paraffin or beneath it.

**Rind rot:** Wet, soft, foul smelling areas on the surface of the cheese beneath the paraffin.

**Rot spots:** Another name for rind rot.

**Rough:** Wrinkled bandage; indentations on the surfaces of the cheese; paraffin lacking smoothness and continuity; scars of paraffining rack on the surface.

**Scaly paraffin:** Loose paraffin which comes off the cheese in small flakes or scales.

**Smooth:** A homogeneous surface or finish without projections, indentations, wrinkled bandage, or cracks.

**Soft spots:** The beginning of rind rot.

**Soiled:** Cheese surfaces which have become dirtied in handling.

**Uneven:** Cheese that is out of shape.

**Wrinkled bandage:** Bandages failing to adhere smoothly to all surfaces of the cheese.

## REFERENCES

American Dairy Science Association (1920). J. Dairy Sci., *3,* 74.

Arbuckle, W. S., Edmondson, J. E. and Mull, L. E. (1940). J. Dairy Sci., *23,* 522.

Downs, P. A. (1937). Neb. Agr. Expt. Sta., Circ. 54.

Fryhofer, C. W. and Potts, R. C. (1923). U. S. Dept. Agr., Office of Secretary, Circ. 157.

Josephson, D. V. (1946). J. Dairy Sci., *29,* 500.

Marquardt, J. C. (1939). J. Dairy Sci., *22,* 430.

Phillips, C. A. and Abbott, F. H. (1932). Cal. Agr. Expt. Sta., Circ. 327.

Trout, G. M. (1939). J. Dairy Sci., *22,* 429.

Trout, G. M. (1943). Personal correspondence.

Trout, G. M., Downs, P. A., Mack, M. J., Fouts, E. L. and Babcock, C. J. (1942). J. Dairy Sci., *25,* 557.

Trout, G. M. and Sharp, P. F. (1937). N. Y. (Cornell) Agr. Expt. Sta., Memoir 204.

Trout, G. M., White, Wm., Downs, P. A., Mack, M. J. and Fouts, E. L. (1939). J. Dairy Sci., *22,* 375.

Trout, G. M., White, Wm., Downs, P. A., Mack, M. J. and Fouts, E. L. (1940). J. Dairy Sci., *23,* 1.

U. S. Department of Agriculture (1943). Food Distribution Administration. Washington, D. C.

Wisconsin State Department of Agriculture (1941). Wisconsin grades and regulations for American cheese. June 1941.

# CHAPTER 19

# TECHNOLOGY OF CHEDDAR CHEESE RIPENING

## Curing Treatments

Cheddar cheese, like many other varieties, must be stored or held for a period of time after making before it becomes edible. When it is taken from the press the cheese is said to be **green, fresh,** or **uncured.** It has no real cheese flavor, merely a mildly acid taste and aroma. The body is relatively firm, elastic and perhaps tough. It is not particularly palatable, although some people enjoy its curdy body and mild flavor.

Green cheese gradually undergoes marked changes as it is held or stored. The extent and nature of these changes depend upon a variety of factors. The body of the cheese loses some of its elasticity and firmness and is then said to be **mellow**; it dissolves easily in the mouth. The cheese develops pleasing flavors and odors. Studies have shown that during this time proteins, fats, carbohydrates, and milk salts undergo marked changes in chemical composition. These changes are the results of the actions of microorganisms and enzymes.

The process during which the chemical and organoleptic properties of the green cheese are so profoundly changed is commonly known as **ripening** or **curing.**

Microorganisms and enzymes in the cheese originate in the milk, starter, and rennet. They are ripening agents which influence the rate of ripening, the extent of ripening, and the nature of the ripening changes. Certain factors controlling these ripening agents are adjusted in the manufacturing operations; they include: moisture content, acidity, and salt content of the cheese. The changes caused by these agents during the ripening process are influenced by the temperature at which the cheese is held, and by the duration of the holding period.

Cheese is considered to be cured for commercial purposes when it no longer has the curdy characteristics of fresh cheese and when it possesses the consistency and flavor intensity desired by the trade. This practical conception of what constitutes cured cheese has naturally resulted in the selling of products of all ages, flavors and consistencies. It is interesting to note what one study has disclosed concerning consumer tastes.

Hobson and Schaars (1935) investigated consumer preferences for different forms of Cheddar cheese. Mild and aged cheese of excellent quality, processed Cheddar cheese, and Cheddar cheese of low quality were all served to 650 college students. Only one form of each cheese was served at their luncheon meal for 7 successive days. Preferences were measured by the amount of cheese consumed per person during the test period. The men rated the different forms in the order—mild, processed, low quality, and aged. The women rated them—processed, low quality, mild, and aged.

In other tests, Hobson and Schaars submitted two samples of cheese of different ages, or kinds, to 6770 adult customers of retails stores in six cities. Mild Cheddar was chosen by 48% of the adults when it was submitted with aged cheese. More men than women liked the aged product. When aged cheese and processed cheese were given out together, 61% of all customers chose the processed cheese; men were evenly divided in their opinions.

Hobson and Schaars continued their tests by serving cheese at the meals of Short Course students (young men from the farm), supervising nurses, and physicians and surgeons. Mild, aged and processed Cheddar cheese were the kinds chosen for the tests; they were served daily for a period of 12 to 15 weeks. The Short Course students preferred processed and cared least for aged cheese. After 4 weeks they ate more processed than both of the other kinds combined. The supervising nurses consumed about the same amounts of mild and processed cheese. They placed aged cheese third and were eating very little of it at the end of the trial. The physicians and surgeons ate more mild cheese than processed during the first part of the trial but they reversed this trend in the last weeks of the tests. They consistently placed aged Cheddar third in these trials.

These tests, as a whole, indicate a good market for aged Cheddar cheese and a better market for the mild or processed type. Evidently most consumers prefer the flavor and consistency of processed Cheddar cheese. The qualities of this product are duplicated best in natural cheese by mild Cheddar. The trials suggest that consumption of cheese can be raised by increasing the number of forms of Cheddar cheese offered for sale. It is apparent all customers cannot be satisfied with one type of flavor and consistency in cheese.

It is necessary to use varied curing treatments to produce the characteristics desired in the finished cheese.

## Development of Modern Curing Treatments

In the early days of factory practice in the United States all cheese was cured without refrigeration. Interest in the effects of refrigeration on cheese quality and composition lead to extensive experiments, especially after 1900.

### DEVELOPMENT OF COLD-CURING

Babcock and Russell (1897), who were studying the bacteriology and chemistry of curing cheese, found that cheese cured at 55° F. and below were invariably of good quality and entirely free from bitterness.

Dean (1899) compared the quality of cheese cured at 60° to 70° F. and found better quality in that held at the lower temperature. Smith (1900) called attention to the results of experiments made in 1899 and 1900 that showed that cheese cured at 60° F. and below averaged at least 5 points higher in flavor and 2.5 points higher in texture than those cured at 65° F. and above.

Babcock, Russell, Vivian, and Baer (1901) used storage temperatures of 15°, 33°, 40°, 50° and 60° F. Their experiments showed that bitter and undesirable flavors were not observed as often in cheese cured at temperatures of 33° to 50° F. Below 32° F. the ripening was not normal, although cheese proteins broke down. The sharp flavors, which were common in cheese cured at higher temperatures, were not produced. Keeping properties of the cheese were better at the lower temperatures. Babcock and Russell (1902) confirmed their earlier reports and emphasized that flavors produced at 33° to 50° F. were mild and clean, and body and texture were smooth, waxy, and solid. Low temperatures, they found, delayed ripening, increased uniformity, and improved keeping properties when compared with curing at 60° F. or higher. They indicated that the mild flavor of cold-cured cheese could be sharpened and intensified by subsequent exposure for a short time to 60° F. Such cheese, they said, should be returned to cold storage as soon as the desired flavor developed.

Dean, Harrison and Harcourt (1902) reported that cheese held at 38° F. required one month to ripen as much as one held at 64° F. would ripen in one week. They too noticed that cheese cured at lower temperature was more uniform.

Van Slyke, Smith and Hart (1903) found that, almost without exception, the cheese cured at 40° was better than that cured at 50°, and the latter was better than that cured at 60° F. These advantages of the lower temperatures prevailed throughout the curing process as shown by the data of table 19:1. The market value of the cheese was increased by the improvement in quality.

TABLE 19:1. AVERAGE SCORES OF CHEDDAR CHEESE DURING STORAGE AT DIFFERENT TEMPERATURES

(Van Slyke, Smith and Hart, 1903)

| *Time in storage* | *Scores at 40°F.* | *Scores at 50°F.* | *Scores at 60°F.* |
|---|---|---|---|
| 10 weeks | 96.3 | 94.7 | 92.0 |
| 20 weeks | 93.8 | 91.5 | 89.7* |
| 28 weeks | 91.2 | 91.9* | — |
| No. cheese, all styles | 104 | 58 | 45 |

*Last score before disposing of cheese.

Dean (1903) and Dean and Harcourt (1903) concluded that holding cheese at 60° F. for a week after making did not injure the quality if the cheese was then moved to 40° F. storage. Dean noted a quality advantage in curing at 40° F. rather than at temperatures of 50° or 60°F. He found no advantage in using 29° F. rather than 40° storage. He ripened cheese for periods of 1, 2, and 3 months at 40° F. and then moved it to 60° F. storage. Comparable lots were held continuously at 40° and 60° F. Cheese held continuously in cold storage scored 93.8; that held in cold storage for 3 months, 92.9; for 2 months, 89.9; for 1 month, 89.3; and that held continuously at 60°F. scored 88.1. These trials emphasized the superiority of 40° F. storage.

Babcock, Russell and Baer (1903) found that close-bodied, firm cheese of fine quality developed flavor faster at 60° F. than the same cheese held at 50° and 40° F. It did not keep as well after reaching its prime; flavor and texture both deteriorated faster at higher temperatures. The 40° curing excelled the other two treatments in developing the best cheese with the longest keeping properties. These workers pointed out that the mildness of flavor and perfection of texture in the cold-cured cheese met a demand that could not be satisfied with the quality of cheese produced by high curing temperatures.

Lane (1906) used curing temperatures of 28°, 34°, and 40° F. and concluded that these differences in temperatures did not materially influence the quality of the cheese.

## Cold-Curing Established

As the result of these extensive experiments over a period of several years in the important cheese-making areas, the commercial practice of cold-curing was soundly established. Today, cold storage warehouses in cheese-making areas accumulate the product as it is shipped from the factory to market. Truck and carload shipments are moved from these warehouses to others in centers of distribution and large markets.

**Temperatures of cold-curing.** Temperatures maintained are usually from 32° to 40° F.; the ideal is commonly regarded as 35° F. Mechanical refrigeration and automatic temperature controls have greatly simplified the equipment, devices and techniques used by the early investigators.

**Humidity in cold-curing rooms.** The relative humidity of low temperature curing rooms usually approximates 75%. This value is apt to be higher in summer than in winter. The relative humidity of the air inside cheese boxes is higher than that of the air of the room in which the boxes are stored; this is because there is some diffusion of moisture through the paraffined surfaces of the cheese. This moisture is partly retained by the box; evaporation is further restricted by the close stacking of the boxes in the curing room. Excessive mold growth on cheese at temperatures of 35° F. may be indicative of excessive humidity but can be caused by unsatisfactory condition of the cheese or the boxes at the time of storage.

**Duration of cold-curing.** The duration of curing varies with the conditions of curing and the flavor intensity desired. Low-temperature storage may last for 3 to 12 months; holding of small amounts of the best quality of cheese for two or even three years is not uncommon.

**Care of cheese in cold-curing.** Cheese to be held in cold-curing rooms is paraffined and placed in clean, dry boxes. Scale boards are placed over and under the cheese in the box; they are placed between cheese that are packed with two flat surfaces together. These scale boards tend to keep the cheese from sticking to the box or to each other. Boxes are stacked in piles of convenient size. Stacks are usually limited in height by the strength of the boxes; wooden boxes are presently preferred for their greater strength although great improvements have been made in paper board boxes. Boxes in the stacks are turned as often as necessary to prevent marked differences in the condition of the ends of the cheese.

**Uses of cold-cured cheese.** Cold-cured cheese is essentially mild in flavor because bacteria and enzymes act more slowly at low temperatures. Cold-curing minimizes defects of a bacteriological nature. Cheese that is properly made from milk of high quality is prized for its keeping properties at low temperatures; such cheese is selected for long storage purposes. Cold-cured cheese is sold as natural cheese; large amounts of it are used in the manufacture of process cheese.

## CONTINUED USE OF WARM-CURING

The practice of curing cheese at temperatures of 50° to 60°F. never entirely disappeared in the United States. In Canada and England the treatment is commonly used. In New Zealand, the normal storage temperature, according to McDowall (1938), is 45° to 50°F.

Riddet, McDowall and Valentine (1933) studied the factors affecting the rate of ripening of New Zealand cheese when it was held under conditions resembling those to which cheese was usually subjected in export. They found that heat-treated milk, carefully manufactured, produced cheese which developed best quality when held first at 60° F. for 4 weeks and then at 45° to 48° F. for an additional 14 weeks. Bitterness associated with immaturity persisted until the lots were almost 18 weeks of age. Soft-bodied cheese were always better when stored at low temperatures; they reached maturity rapidly but deteriorated quickly. Excessive firmness in highly salted cheese was slow to change in ripening under any condition; such cheese gave an undesirable harsh body even when cured at 60° F. for 42 days. High temperatures caused more open texture but good cheese tended to close somewhat when cooled.

Reichart (1935) studied the ripening of cheese protected by valve-vented cans and found that cheese made from pasteurized milk of good quality ripened in 30 to 40 days at 60°-75° F. and gave a high scoring cheese. Later, McCubbin and Reichart (1937) ripened Cheddar cheese in vented cans held at 70° and 40° F. The cheese ripened at 40° F. was continuously superior in both body and flavor.

Freeman and Dahle (1938) reported that the maximum flavor score was reached more quickly in ripening at 63° F. than at 45° F. They associated bitter flavor with ripening at the higher temperature.

McDowall (1938) stored cheese 10 weeks at 45°-50° F. and some identical lots for shorter intervals at 31° and 14°F. His judges observed some improvement in body and flavor in the lots held at 31° F. Flavors were milder at the lower temperature.

Marquardt (1939) observed that curing at low temperatures of 35° to 40° F. delayed good, as well as bad, flavor development but produced cheese of better quality. He felt that combinations of low and high temperatures were desirable to force the curing of the cheese.

Wilson, Hall and Johnson (1941) studied the relationship of curing temperatures to the quality of Cheddar cheese. They used milk of exceptionally fine quality. They divided each of 116 vat lots of cheese among four storage treatments. Six months at 34° F. was used as the control to simulate usual practices. The other treatments were: 3 months at 50°F. plus 3 months at 34° F.; 6 months at 50° F.; and 3 months at 60° F. plus 3 months at 34°F. Relative humidity of the storages was 70 to 75%. When all lots were 6 months of age, these workers preferred the quality of the cheese subjected to curing for all or a part of the time at 50° F. because from 52.5 to 57.5% of these lots scored higher than identical cheese stored at 34° F. Those lots of cheese stored at 50° and 34° F. averaged 0.28 points higher in score than the controls. Those lots stored for 6 months at 50° F. averaged only 0.13 points better than the controls. Storage at 60° F. and 34° F. reduced the average quality 0.16 points below that of the controls. When Wilson, Hall and Johnson divided the lots of cheese cured at 50° F. for 6 months according to quality, they found that approximately 70% of lots scoring 92 or more were better than identical cheese held at 34° F. for the same length of time. Seventy per cent of those scoring less than 92 were inferior to their controls held at 34° F. They stated that the lower temperature of storage suppressed unfavorable changes resulting from faulty manufacturing procedures and delayed the development of characteristic Cheddar flavor in properly made cheese.

Reichart and Downs (1941) studied the influence of temperature of curing on the quality of Cheddar cheese protected by different coverings. They found that the cheese ripened at 45° F. was almost without exception of better quality than that ripened at 65°F.

Dahlberg and Marquardt (1912) reported that cheese made from raw or pasteurized milk of the finest quality cured slowly in cans at 40°F. and lacked flavor after 12 months. They preferred the flavor produced by holding cheese in cans at 50°F. for 4 months or even at 60°F. for 2 months. They preferred cold curing for cheese made from milk of inferior quality.

Hanson, Arbuckle, and Shepardson (1944) cured pasteurized-milk cheese in valve-vented cans at 45°, 60°, 70°, and 80°F. They used various combinations of temperature treatments in their attempts to obtain the best possible quality in the shortest practical period of ripening. They succeeded in producing high quality cheese in 4 weeks by holding it two weeks at 45°F. and two weeks at 60°F. The best cheese produced in 8 weeks of curing was ripened for two weeks at 45° and 6 weeks at 60°F. This cheese was superior to that ripened in 4 weeks.

Wilson, Hall and Rogers (1945) observed the undesirable effects of milk of inferior quality on the grade of cheese cured at 60°F. They concluded that cheese, when properly made from desirable pasteurized milk, could be ripened best at 50°F. and possibly higher. Temperatures as low as 34°F., they believed, should be used for storage purposes only.

Sanders, et al. (1946) in a preliminary report on the ripening of Cheddar cheese made from pasteurized milk, stated that cheese held at 60°F. ripened more quickly and had more flavor than that cured at 50°F. Three to four months ripening at 60° was equivalent in their experiments to 6 months at 50°F. Such cheese usually was slightly firmer, crumblier, and shorter in body but not objectionably so. Curing at 60°F. for longer than 4 to 6 months sometimes produced an objectionable, short, mealy body. When they used low-grade milk, either raw or pasteurized, they preferred the quality of the cheese held at 50°F. over that held at 60°F. A temperature of 70°F., they stated, was too high for cheese of any quality.

Erekson (1946) called attention to the continued industrial application of shelf-curing. He cited the process patented by Coon (1926) for producing the black, wax-coated cheese which was known in the trade as "Coon Cheese." Erekson credited Coon with recognizing and supplying the demand for the highly flavored, shelf-cured cheese. He also called attention to the Waters (1933) patent which described the use of 55° to 65°F. temperatures, relative humidities exceeding 95%, turning of the cheese every two or three days, and wiping of the cheese with a saturated solution of disodium phosphate. Erekson advocated the use of carefully selected raw-milk cheese to obtain the high, typical flavor of the shelf-cured product but stated that such cheese appealed only to a limited market. He wisely cautioned that profits from high-temperature curing could be made only if the cheese commanded a premium sufficient to compensate for shrinkage, expense of preventing insect damage, and costs of extra labor and extra space required for shelf-curing. He indicated that the high flavor induced in pasteurized-milk cheese by shelf-curing was not comparable to that obtained by curing selected raw-milk cheese under similar conditions.

## WARM-CURING PRACTICES

The continuing demand for cheese with high flavor has encouraged warm-curing of Cheddar cheese. It is practiced commercially on the large scale. The general improvement in the quality of milk used for cheese and the increased amounts of cheese made from pasteurized milk tend to decrease the risk of warm-curing practices. Relatively high temperatures can be used with greater assurance of satisfactory flavors when such milk is used.

**Temperatures for warm-curing.** The high-temperature curing process utilizes temperatures of 50° to 60° F. The most common range is 55° to 60°F.

**Humidity in warm-curing.** The relative humidity of air in warm curing rooms is held at not less than 85%. If the relative humidity exceeds approximately 93%, the cheese tends to absorb moisture; it becomes unnaturally light in color in the rind portion. Eventually, when cheese is held at this excessively high humidity, it becomes soft and develops rind-rot.

**Paraffining for warm-curing.** Cheese to be warm cured is placed on shelves to facilitate handling and turning; this accounts for the common name, shelf-curing. It is cured with or without paraffin, although most operators prefer to minimize mold growth by applying the paraffin before curing. If the cheese has been cured without paraffin, it is commonly dipped without cleaning before it is boxed. The mold, which grows vigorously on this cheese, turns black when the cheese is dipped in paraffin. Such moldy cheese should be merchandised promptly because mold growth reduces the acidity of the surface of the cheese. The lower acidity enables proteolytic organisms to grow, even beneath the paraffin, and sooner or later the cheese develops rind-rot.

**Duration of the warm-curing treatment.** Curing at high temperatures usually continues for 6 to 18 weeks. Such cheese, which may have been stored at 35°F. before the warm-curing treatment, may then be moved to low-temperature rooms for holding for a short time, two to six weeks, before marketing. Cheese that is relatively free of mold or other rind defects can be held longer at the low temperature without excessive risk of spoilage.

**Care of cheese in warm-curing.** The cheese is held on open shelves and turned often enough, usually at three to seven day intervals, to maintain similar rind conditions on each flat side of the cheese. Some operators rub oil on the cheese to minimize evaporation losses and to delay mold growth; others turn and rub the cheese with pieces of burlap to delay mold growth. A few operators turn the cheese without rubbing in order to encourage the development of uniform mold growth on all surfaces. Since the mold turns black when the cheese is paraffined, this color is often associated with aged cheese by the trade.

Cleanliness in high-temperature curing rooms is essential. Crumbs of cheese, or accumulations of mold on shelves, encourage insect infestations. Cheese mites and cheese skippers destroy the market value of the cheese. Products so infested are considered to be adulterated under the provisions of the Food, Drug and Cosmetic Act. High-temperature curing rooms are fumigated when necessary to eliminate insect pests. Fumigation with methyl bromide is effective and does not injure the cheese, according to Roehm, Stenger and Shrader (1943). Fumigation should be used only with proper precautions and by trained personnel.

**Uses of warm-cured cheese.** **Shelf-cured** cheese is sometimes called **forced-cured, fast-cured** or **warm-cured.** Merchandisers use special trade names to identify such cheese; as an example, the name "Coon Cheese" is well known in the industry. In Canada a similar product is sold under the brand name of "Black Diamond." Cheese cured by this method has distinctive sharp flavor that is chosen by some people; older men especially seem to have such preferences.

The high flavor of shelf-cured cheese is attained in approximately 3 months and, as a result, the product is in demand for the process cheese industry. The greater shrinkage in weight of the cheese and its outward appearance after high-temperature curing are of no moment in processing. Low moisture content is sometimes advantageous in making process cheese and is always subject to adjustment when necessary. Manufacturers are beginning to use Pliofilm wrappers and special boxes to minimize drying and moldy growth. The balance of flavors in normal shelf-cured cheese is frequently inclined to be harsh or imperfect: processing tends to soften and blend the harsh volatile odors so that shelf-cured cheese is not objectionable for processing.

Pasteurized-milk cheese, which always ripens more slowly than raw-milk cheese, is being cured in increasing amounts at temperatures approximating 50 F. This is entirely feasible for cheese to be consumed in the natural form, when it is enclosed in moisture proof, mold inhibiting wrappers and boxes. Pasteurized-milk cheese is being force-cured in large amounts for use in both natural cheese and process cheese trades.

## PRECAUTIONS IN COLD-CURING AND WARM-CURING

**Selection.** It is not good practice to store cheese which will not improve with the holding conditions to be used. Skilled judges make these decisions. They consider detectable faults in raw material, manufacturing operations, or treatment of the cheese after manufacture. These faults are balanced against a knowledge of the effects of the curing operations. Excessively acid cheese, for example, does not improve with cold-curing so it is better to sell it without the added expense of storage. Again, cheese that is too sweet develops carbon dioxide so fast at high temperatures that it soon becomes defective in texture. The best quality of cheese for curing at any temperature, as a general rule, is practically perfect in flavor, body, texture, color and finish.

**Surface condition of cheese.** The finish of cheese to be cured should be practically perfect because damage to the rind invariably results in mold growth or insect infestations. Loose or wrinkled bandages, rough finish, cracked or checked rinds, mold spots, broken paraffin, are defects which disqualify cheese for long curing at low temperatures or for short curing at high temperatures.

**Supervision of curing operations.** Careful supervision of cheese in curing is insurance for the investment involved. The cheese is examined periodically for changes in flavor, body, texture, finish. In this way the time of developing the ideal quality of the cheese can be ascertained and proper disposition can be made of the product. In a like manner, close supervision reveals deterioration in quality. Cheese showing such deterioration can be moved out of storage and into proper channels for use before any monetary loss is sustained. Supervision of curing involves inspection of the sanitary condition of the storage rooms. Clean rooms, freedom from excessive mold growth, absence of insect pests, proper appearance of the cheese on shelves or in boxes, detection of broken boxes which might cause stacks of cheese to fall, and maintenance of correct temperature and humidity conditions, are some of the more important items which are checked in carefully supervised curing.

## FREEZING OF CHEESE

Freezing of cheese in transit may damage the product. Such accidents have aroused interest in the effects of low temperatures on the characteristics of cheese.

**Freezing point of Cheddar cheese.** The freezing point of cheese depends upon the freezing point of the complex solution of the cheese constituents in the moisture content of the cheese. In fresh Cheddar cheese the substances in solution in the cheese moisture include lactose, milk salts, and the sodium chloride added for seasoning. As the cheese ripens, more of the dry matter of the cheese becomes water-soluble and the freezing point is consequently lowered. There is a gradual loss of water by evaporation during the ripening process so that the percentage of substances dissolved in the cheese moisture gradually increases, thus the freezing point is further lowered.

Watson and Leighton (1927) observed the freezing points of several varieties of cheese, including Cheddar and Cottage. They reported freezing points of 29.8°F. for one sample of Cottage cheese with 78.7% moisture, 8.8°F. for a lot of Cheddar containing 33.8% moisture, and 19.6°F. for one sample of processed Cheddar containing 38.8% moisture.

Sommer (1928) and Price (1935) measured the freezing points of Cheddar cheese. Sommer found one lot out of 14 that froze at 24.3°F. and another lot as low as 6.2°F. Price observed freezing points in 18 lots of cheese ranging from 22.6°F. downward to 13.1°F. Table 19:2 combines the observations of these two workers and shows freezing points and moisture contents of 32 lots of Cheddar cheese ranging in age from 23 to 501 days.

The data of table 19:2 indicate a general trend for younger lots of cheese to freeze at higher temperatures than aged lots. High moisture contents seem to be found more often in younger lots of cheese with the higher freezing points; this relation however, is not too striking in the data of table 19:2.

TABLE 19:2. FREEZING POINTS OF CHEDDAR CHEESE
(Data from Sommer, 1928, and Price, 1935)

| *No. of lots* | *Age Class* | *Age* | | *Freezing points* | | *Moisture* | |
|---|---|---|---|---|---|---|---|
| | | *Min.* | *Max.* | *High* | *Low* | *High* | *Low* |
| | Months | days | days | °F. | °F. | % | % |
| 12 | 0- 4 | 23 | 112 | 24.3 | 19.2 | 38.1 | 33.2 |
| 7 | 4- 8 | 126 | 168 | 19.9 | 17.6 | 37.1 | 32.5 |
| 5 | 8-12 | 266 | 347 | 19.0 | 12.4 | 38.1 | 33.2 |
| 8 | over 12 | 381 | 501 | 17.6 | 6.3 | 33.9 | 30.8 |

**Effect of freezing on quality of Cheddar cheese.** Industrial impressions of the effect of freezing on Cheddar cheese are based chiefly upon the unfavorable results of accidental exposure to freezing temperatures. Investigations of the influence of freezing have disclosed that cheese may or may not be damaged severely by the treatment. The results depend upon the conditions of freezing and the subsequent treatments of the cheese.

Babcock and Russell (1897) stored Cheddar cheese for several months at 15° F., which was below the freezing point of the fresh cheese. The cheese were usually only fair in quality when defrosted but they improved rapidly when held at 40° F. and often developed good flavor and texture.

Lane (1906) stored several styles of Cheddar cheese at 5° F. The cheese solidified and developed ice on the surface; the tops and sides became lumpy from expansion in the interior of the cheese. After six months they were removed from storage and defrosted at 70° F. The defrosted cheese cut well but dried out rapidly and became crumbly. It was mottled in appearance. No ripening occurred at this temperature. Lane concluded that the treatment was entirely unsatisfactory and unprofitable.

Sommer (1928) subjected six lots of cheese to temperatures approximating 0° to −10° F. for seven days. Identical lots were not frozen. They were defrosted, held for a month in a cheese curing room and were then scored. The identical lots, which had not been frozen, were scored at the same time. The judges could not distinguish between the lots in flavor; the frozen cheese, however, averaged 0.71 points less in texture score than the controls. Cheese which had been frozen was crumbly; it was seamy in color; it tended to dry and crack in the surface layers.

It was improved by holding at curing room temperatures. The paraffin flaked off the cheese. Cheese with close texture suffered less damage in freezing than did cheese that was open in texture.

Price (1935) successfully applied the principles of fast-freezing (20 to 30 minutes) to the preservation of packaged Cheddar cheese. Like other investigators, he reported the damaging effects of slow freezing, such as might be encountered by exposure to freezing conditions in transit. But when he froze cheese quickly, in 20 to 30 minutes, his judges were not able to distinguish it from identical cheese which had not been subjected to the freezing and defrosting treatments. He placed fully ripened cheese in sealed packages, fast froze it, stored it at 0°F. for 12 months, and found it excellent in quality after defrosting.

Marquardt (1937) reported that he had held Muenster, Limburger, Cheddar, Camembert and a grating cheese in frozen storage to delay curing changes.

McDowall (1938) tried freezing as a possible method of preserving the quality of Cheddar cheese at any desired stage of maturity. He was not encouraged by his findings. Storage at 14°F. produced an abnormal product. The cheese was crumbly and shattered in appearance. These effects were not so apparent in cheese which had been ripened at 45° to 50°F. for 160 days before freezing. But even mature cheese which had been frozen for 60 days was unattractive after defrosting. The frozen cheese was soapy, insipid, and somewhat tallowy in flavor. Holding cheese at 45° to 50°F. for two months after defrosting improved both texture and flavor, but did not completely eliminate the defects.

## REFERENCES

Babcock, S. M. and Russell, H. L. (1897). Wis. Agr. Expt. Sta., 14th Ann. Rept. 194.

Babcock, S. M. and Russell, H. L. (1902). Wis. Agr. Expt. Sta., Bul. 94.

Babcock, S. M., Russell, H. L., and Baer, U. S. (1903). U. S. Dept. Agr., Bur. An. Ind., Bul. 49. The western experiments, pp. 11-70.

Babcock, S. M., Russell, H. L., Vivian, A., and Baer, U. S. (1901). Wis. Agr. Expt. Sta., 18th Ann. Rept. 136.

Coon, Edward William (1926). U. S. Patent 1,579,196 (Mar. 30, 1926).

Dahlberg, A. C. and Marquardt, J. C. (1942). N. Y. (Geneva) State Agr. Expt. Sta., Tech. Bul. 265.

Dean, H. H. (1899). Ont. Agr. Col. and Expt. Farm, Report 1899, pp. 54-74.

Dean, H. H. (1903). Ont. Agr. Col. and Expt. Farm, Report 1903, pp. 60-76

Dean, H. H. and Harcourt, R. (1903). Ont. Agr. Col. and Expt. Farm Bul 131.

Dean, H. H., Harrison, F. C. and Harcourt, R. (1902). Ont. Agr. Col. and Expt. Farm Bul. 121.

Erekson, A. B. (1946). Food Ind. *18,* 8:81.

Freeman, T. R. and Dahle, C. D. (1938). Pa. Agr. Expt. Sta., Bul. 362.

Hanson, F. E., Arbuckle, W. S. and Shepardson, C. N. (1944). Texas Agr. Expt. Sta., Bul. 646.

Hobson, Asher and Schaars, Marvin A. (1935). Wis. Agr. Expt. Sta., Res. Bul. 128.

Lane, C. B. (1906). U. S. Dept. Agr., Bur. An. Ind. Bul. 83.

Marquardt, J. C. (1937). J. Dairy Sci., *20,* 468.

Marquardt, J. C. (1939). Natl. Butter and Cheese J., *30,* 9:28.

McCubbin, W. G. and Reichart, E. L. (1937). J. Dairy Sci., *20,* 466.

McDowall, F. H. (1938). New Zealand J. Sci. and Technol., *20,* 1:31a-40a.

Price, Walter V. (1935). Wis. Agr. Expt. Sta., Res. Bul. 130.

Reichart, E. L. (1935). J. Dairy Sci., *28,* 477.

Reichart, E. L. and Downs, P. A. (1941). J. Dairy Sci., *24,* 19.

Riddet, W., McDowall, F. H. and Valentine, G. M. (1933). N. Z. Dept. of Sci. and Ind. Res., Bul. 38.

Roehm, L. S., Stenger, V. A. and Shrader, S. A. (1943). J. Dairy Sci., *26,* 205.

Sanders, George P., Tittsler, R. P., Walter, H. E., Sager, Oscar S., Lochry, R. and Geib, D. S. (1946). U. S. Dept. Agr., Agr. Res. Adm., Bur. Dairy Ind. BDIM–Inf–29. Feb., 1946.

Smith, G. A. (1900). N. Y. (Geneva) Agr. Expt. Sta., Bul. 184, pp. 193-203.

Sommer, H. H. (1928). J. Dairy Sci., *11,* 9.

Van Slyke, L. L., Smith, G. A., and Hart, E. B. (1903). N. Y. (Geneva) Agr. Expt. Sta., Bul. 234.

Waters, Henry L. H. (1933). U. S. Patent 1,910,195. (May 23, 1933).

Watson, Paul D. and Leighton, Alan (1927). J. Dairy Sci., *10,* 331.

Wilson, H. L., Hall, S. A. and Johnson, W. T., Jr. (1941). J. Dairy Sci., *24,* 167.

Wilson, H. L., Hall, S. A. and Rogers, L. A. (1945). J. Dairy Sci., *28,* 187.

## CHAPTER 20

# TECHNOLOGY OF CHEDDAR CHEESE RIPENING

## Losses of Weight in Ripening

Losses of weight during ripening can be considered to be a normal phenomenon and a part of the cheese making process. If the losses in weight are excessive, as they may be under some circumstances, or if they are minimized by using special wrappers or containers, the normal trends of ripening may be greatly altered. Losses in weight of cheese during ripening are sometimes called **shrinkage.** These losses are caused by evaporation of moisture, by development of carbon dioxide, and by exudation of fat. Of these three causes, the first is the most important.

### LOSSES OF FAT

The leaking of fat from cheese occurs at abnormally high temperatures. Cheese that is paraffined and then held at 65°F. or more soon exudes oil through the paraffin coating. Higher temperatures of holding increase the losses. Aged cheese seems to release the fat more readily than fresh cheese. Heavy rind formation decreases the tendency to lose fat.

The amount of fat which may be lost in this manner has not been carefully measured. The amount is indicated roughly by the curves in figure 20:1. The data upon which these curves are based were reported by Van Slyke (1901). During the first week of curing the loss of weight was rapid regardless of the temperature of holding. Weekly losses decreased as the cheese aged at 55° and 60°F. But the cheese held at 80°F. began to lose weight *more* rapidly after the fourth week. The loss in weight per week per hundred pounds of cheese held at 80° averaged 12.4, 13.2, and 15.6 ounces during the second, third and fourth months of aging. Cheese held at 55° lost 6.0, 3.6, and 2.8 ounces per hundred pounds during the second, third and fourth months of curing. Van Slyke believed that the increased loss of weight per week in the cheese aged at 80° was caused by leakage of fat from the cheese.

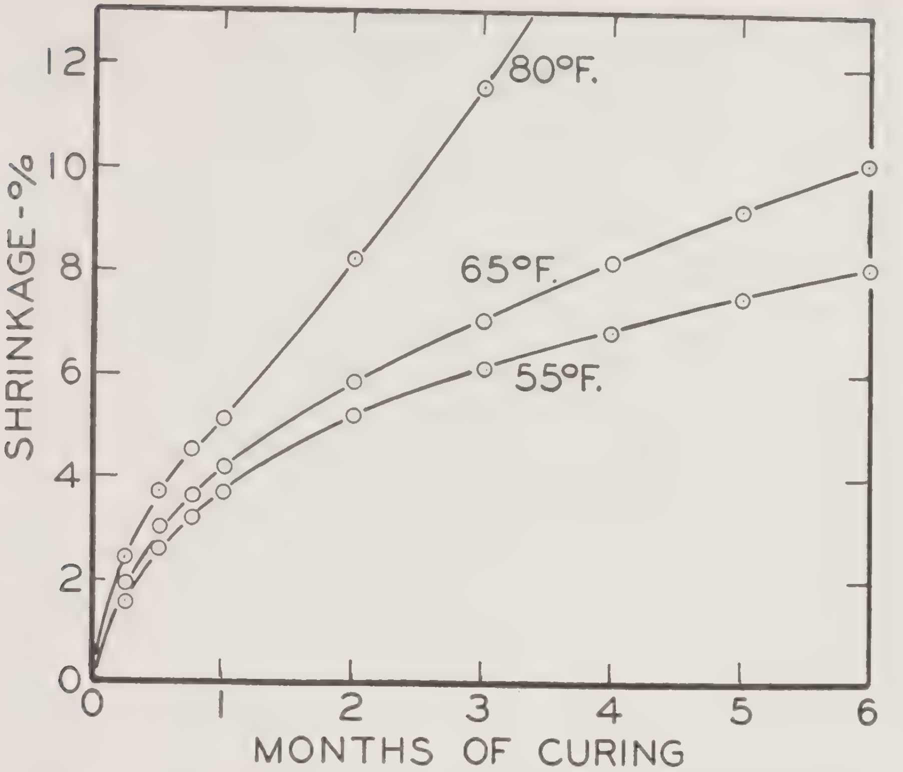


Figure 20:1. The amount of moisture lost in the curing of cheese increases as the temperature of holding increases. Van Slyke (1901) reported the observations on which this figure is based. The cheese were non-paraffined cheddars, held at 75% relative humidity. The loss of weight at 80°F. amounted to 15.4% after 4 months of holding; this point is not plotted in this graph.

## LOSSES OF CARBON DIOXIDE

Evolution of carbon dioxide in the ripening of cheese is highly variable. Tretsven (1945) pointed out that the amount produced by Cheddar cheese was influenced by the quality of milk used in making the cheese, pasteurization of milk, temperature of storage, time of storage, initial acidity of the cheese and the presence of gas producing organisms. Golding (1944) found that *Lactobacillus bulgaricus* used with lactic starter in making Cheddar cheese decreased the amount of gas evolved during ripening. Dorn and Dahlberg (1942) reported that the loss in weight of Cheddar cheese in the form of carbon dioxide varied from 0.13 to 0.20% of the weight of the raw-milk cheese and 0.04 to 0.09% of the weight of pasteurized-milk cheese. Van Slyke and Hart (1903) measured the gas evolved by a cheese for 32 weeks and accounted for 15.099 grams, equal to 0.5% of the weight of the fresh cheese.

The evolution of carbon dioxide is influenced by so many variable factors that it is impossible at this time to assign a practical value to indicate the extent of the loss. Fortunately, it is not an important factor in shrinkage losses.

## LOSSES OF MOISTURE

The rapidity and extent of loss of moisture, during the ripening of cheese vary with several interdependent conditions. Those of chief interest for practical reasons are: (1) the temperature of the curing room or storage; (2) the proportion of water vapor present in the air of the room; (3) the use of paraffin on the cheese; (4) size and shape of the cheese; (5) moisture content of the cheese; and (6) the quality of the cheese. Numerous studies were made of these factors from 1895 to 1915. The experiment stations in New York, and Wisconsin, the United States Department of Agriculture and the Ontario Agricultural College were prominent among those reporting on this subject. The question still receives deserved attention. It is not possible to review all of the significant contributions to our information on this subject; certain ones have been selected for discussion to illustrate trends of factors affecting losses in weight during curing.

**Humidity and shrinkage.** Storage of cheese in a room with high relative humidity minimizes evaporation losses from cheese surfaces. Such a condition is maintained in the shelf-curing process. Van Slyke (1901) demonstrated this effect by holding one cheese at 60° F. in a room in which the air was 75 to 80% saturated with moisture while another identical cheese was kept under a bell jar where the air was completely saturated with moisture. In 15 months the first cheese lost over 11 per cent of

TABLE 20:1. CHANGES IN WEIGHT CAUSED BY DIFFERENCES IN HUMIDITY OF STORAGE AT 60°F.
(Van Slyke, 1901)

| *Age of cheese* | *Relative humidity 75 to 80%* | *Relative humidity 100%* |
|---|---|---|
| | *Loss in weight* | *Gain in weight* |
| *months* | % | % |
| 1 | 0.76 | — |
| 2 | 1.13 | 0.08 |
| 6 | 4.12 | 0.11 |
| 12 | 9.69 | 1.70 |
| 15 | 11.14 | 1.92 |

its weight; the other gained almost 2 per cent in weight. These results are shown in detail in table 20:1.

Babcock, Russell and Baer (1903), noticed that cheese stored in boxes at low temperatures did not lose weight as rapidly as cheese stored in boxes at higher temperatures. They offered data to explain this fact. They measured the relative humidity inside the boxes and found that in boxes of cheese stored at 35°-40°F. the air was saturated with moisture; at higher temperatures the relative humidity of the air in the boxes was low enough to permit evaporation of moisture from the cheese. Their results are shown in table 20:2.

TABLE 20:2. COMPARISON OF RELATIVE HUMIDITY OF AIR IN ROOM AND AIR IN CHEESE BOXES

(Babcock, Russell and Baer, 1903)

| *Room temperatures* | *Relative humidity* | |
|---|---|---|
| | *Room* | *Cheese box* |
| °*F.* | % | % |
| 35–40 | 85–92 | 100 |
| 50–55 | 55–75 | 94 |
| 60–69 | 50–70 | 84–90 |

**Temperature and shrinkage.** The shrinkage of cheese is less at low temperatures than at high temperatures. This general conclusion has been supported by practically all work on the subject by numerous investigators. Figure 20:1 shows Van Slyke's (1901) observations on losses of weight from cheese stored for six months at 55°, 65° and 80°F. The cheese were non-paraffined cheddars weighing approximately 65 pounds each. The relative humidity of the storage rooms was maintained at 75%. The lowest temperature caused the least shrinkage. Increasing the temperature increased the weekly rate of loss of moisture. Losses were greatest during the first week of storage. Curing at the abnormally high temperature of 80°F. caused an acceleration in weekly rate of shrinkage after the fourth week but this was attributed to the obvious leakage of fat from the cheese.

Van Slyke's (1901) data are particularly interesting because they indicate the comparatively rapid loss of moisture that occurs during the first week or two of curing. The surface of the freshly made cheese is moist. As the water evaporates a rind layer forms; the rate of loss of moisture decreases as the thickness of the rind increases. Some rind formation is necessary before cheese can be properly paraffined. In commercial practice cheese is allowed to dry for 3 to 10 days before paraffining. Drying room temperatures approximate 55° to 65° F. so that the curves of figure 20:1 are particularly significant whether the cheese is to be shelf-cured or merely dried for paraffining at these temperatures. Sammis and Bruhn (1912) compiled data of similar interest on the shrinkage of daisy style cheese before paraffining. Their lots of cheese were held in a well ventilated room in which the temperature sometimes reached 70° F. Their data, showed that shrinkage averaged approximately three and one-half per cent in one week and around five pounds in 13 to 19 days. These statistics appear in table 20:3.

TABLE 20:3. SHRINKAGE OF DAISY-STYLE CHEESE BEFORE PARAFFINING *
(Sammis and Bruhn, 1912)

| *Age when paraffined* | *Number of lots* | *Shrinkage per 100 pounds green cheese* | |
|---|---|---|---|
| | | *Pasteurized-milk cheese* | *Raw-milk cheese* |
| *days* | | *lb.* | *lb.* |
| 7– 8 | 11 | 3.95 | 3.56 |
| 9 | 5 | 4.31 | 3.88 |
| 10 | 16 | 4.35 | 3.83 |
| 11 | 12 | 4.52 | 4.10 |
| 12 | 10 | 4.84 | 4.17 |
| 13–19 | 11 | 5.29 | 4.78 |

* Cheese was dried in a well ventilated room where the temperature sometimes reached 70°F.

The influence of the temperature of storage upon shrinkage of cheese was studied cooperatively by the United States Department of Agriculture, the New York Agricultural Experiment Station and the Wisconsin Agricultural Experiment Station. A few of the results of these studies are presented in table 20:4. These collaborators showed that losses of moisture were least at 40° F., higher at 50° F. and highest at 60° F. for any given style of cheese in the study. Shrinkage of weight increased as the size of the style of cheese decreased. Differences in shrinkage were reported for the same styles of cheese in different storages. These cheese were held in boxes.

Table 20:5 shows the shrinkage in weight of non-paraffined cheese stored in boxes at 28°, 34°, and 40° F. These data resulted from the work of Lane (1906). Shrinkage at 28° F. was

TABLE 20:4. SHRINKAGE OF NON-PARAFFINED CHEESE IN BOXES IN COMMERCIAL STORAGE AT 40°, 50°F. AND 60°F.

| *Size of cheese* | *Age into storage* | *Age at weighing* | *Weight loss per 100 lb. of cheese* | | |
|---|---|---|---|---|---|
| | | | *40°F.* | *50°F.* | *60°F.* |
| | *days* | *weeks* | *lb.* | *lb.* | *lb.* |
| (Data from Van Slyke, Smith and Hart, 1903) | | | | | |
| Cheddars | 8–14 | 17–20 | 3.9 | 4.4 | 6.6 |
| Flats | 9 | 19–20 | 4.1 | 6.0 | 8.7 |
| Y. A.'s | 8 | 20 | 4.6 | 8.1 | 12.0 |
| (Data from Babcock, Russell and Baer, 1903) | | | | | |
| Flats | 5–17 | 23 | 1.3 | 5.0 | 5.6 |
| Daisies | 5–17 | 21 | 1.9 | 2.8 | 5.6 |
| Prints | 5–17 | 24 | 2.6 | 7.5 | 11.1 |

less than at the other temperatures used and was less than half as much as the shrinkage at 40°F. These lots of cheese were placed in storage at approximately two weeks of age so that the shrinkage losses reported do not include the amounts lost after pressing and before storage.

According to the data which have been presented, higher temperatures of storage cause greater losses in weight. It is not possible with the data available to state that a certain percentage of weight will be lost at any given temperature. Some of the reasons for the variations in rates of loss will be indicated in the discussions of some of the other factors that influence rate of evaporation of moisture from the cheese.

**Size and shape of cheese and shrinkage.** Tables 20:4 and 20:5 show losses of moisture when different styles of cheese were stored at different temperatures. The larger styles of cheese tended to lose less moisture than the smaller styles. An exception is shown in table 20:5 in which the flats lost less moisture than the cheddars. The explanation of the trend was not specifically mentioned by Lane (1906) but differences in the prop-

TABLE 20:5. SHRINKAGE OF NON-PARAFFINED CHEESE IN BOXES IN COMMERCIAL STORAGE AT 28°, 34°, AND 40°F.

(Lane, 1906)

| *Style of cheese* | *Age when stored* | *Percentage of weight loss in 6 months* | | |
|---|---|---|---|---|
| | | *At 28°F.* | *At 34°F.* | *At 40°F.* |
| | *weeks* | % | % | % |
| Cheddar | 2 | 1.81 | 4.18 | 4.68 |
| Flats | 2 | 1.71 | 3.21 | 3.90 |
| Y. A.'s | 2 | 2.83 | 5.02 | 6.81 |

TABLE 20:6. MOISTURE LOST BY NON-PARAFFINED CHEESE OF DIFFERENT WEIGHTS WHEN HELD IN COMMERCIAL STORAGE IN BOXES FOR 5 MONTHS

(Van Slyke, Smith and Hart, 1903)

| *Average weight of cheese* | *Moisture lost by 100 pounds of cheese* | | |
|---|---|---|---|
| | *At 40°F.* | *At 50°F.* | *At 60°F.* |
| *pounds* | *pounds* | *pounds* | *pounds* |
| 70 | 2.5 | 2.4 | 4.2 |
| 45 | 2.7 | 3.7 | 5.1 |
| 35 | 3.9 | 5.9 | 8.5 |
| 12½ | 4.6 | 8.1 | 12.0 |

erties of the cheese, such as moisture or texture, or the amount of drying which occurred before the lots were received, weighed and stored, might well cause such differences in rates of loss.

Van Slyke, Smith, and Hart (1903) classified some of the lots of cheese in their investigations to show the relation between the weight of the cheese and loss of moisture. They observed that small cheese lost a larger proportion of moisture in curing than larger styles. This they attributed to the greater amount of surface relative to weight in the smaller styles. Variations in losses between different styles were much less at lower than at higher temperatures. Their results are shown in table 20:6. More data of a similar nature are presented in tables 20:4 and 20:5.

**Paraffining and shrinkage.** Paraffining of cheese reduces losses of moisture in storage. The extent of the reduction depends on such factors as the composition of the cheese, the amount of drying before paraffining, temperature and duration of storage, type of paraffin, and method of paraffining. Sys-

TABLE 20:7. INFLUENCE OF PARAFFINING ON LOSS OF WEIGHT DURING 5 MONTHS STORAGE

(Data from Van Slyke, Smith and Hart, 1903)

| *Storage temperature* | *Treatment* | *Number of cheddars* | *Total weight* | *Weight lost* |
|---|---|---|---|---|
| *°F.* | | | *lb.* | % |
| 40 | Paraffin | 10 | 714 | 0.3 |
| | None | 29 | 1940 | 3.9 |
| 50 | Paraffin | 6 | 420 | 0.5 |
| | None | 15 | 982 | 4.4 |
| 60 | Paraffin | 4 | 280 | 1.4 |
| | None | 12 | 797 | 6.6 |

tematic studies of each of these effects have not been reported. Trends of some of these effects can be illustrated with data now available.

Table 20:7 shows the influence of paraffining on loss of weight from paraffined and non-paraffined cheddars during 5 months of storage at three different temperatures. Losses of weight of the non-paraffined cheese were greater than those of the paraffined cheese when storage temperatures were high; the ratios of non-paraffined to paraffined losses were largest at the lower temperatures.

Lane (1906) stored cheese in boxes at approximately two weeks of age; half of the lots were paraffined. He observed losses in weights after approximately 2, 4, 6, and 8 months of storage.

TABLE 20:8. MOISTURE LOST BY CHEDDARS* IN STORAGE
(Lane, 1906)

| *Storage temperature* | *Treatment* | *Moisture lost by 100 pounds of cheese* | | | |
|---|---|---|---|---|---|
| | | *63 days storage* | *126 days storage* | *185 days storage* | *247 days storage* |
| *°F.* | | *lb.* | *lb.* | *lb.* | *lb.* |
| 40° | Paraffin | 0.91 | 1.64 | 2.02 | 3.19 |
| | None | 2.27 | 3.68 | 4.68 | 5.87 |
| 34° | Paraffin | 0.27 | 0.72 | 1.34 | 1.36 |
| | None | 1.62 | 2.88 | 4.18 | 5.12 |
| 28° | Paraffin | 0.19 | 0.37 | 0.61 | 1.27 |
| | None | 0.93 | 1.48 | 1.81 | 2.88 |

* Stored in boxes at approximately 2 weeks of age; 16 cheddars were stored at each temperature, 8 were paraffined, 8 were not.

TABLE 20:9. MOISTURE LOST BY FLATS* IN STORAGE
(Lane, 1906)

| *Storage temperature* | *Treatment* | *Moisture lost by 100 pounds of cheese* | | | |
|---|---|---|---|---|---|
| | | *63 days storage* | *126 days storage* | *185 days storage* | *247 days storage* |
| *°F.* | | *lb.* | *lb.* | *lb.* | *lb.* |
| 40° | Paraffin | 0.49 | 1.14 | 1.46 | 2.17 |
| | None | 1.62 | 2.75 | 3.90 | 5.53 |
| 34° | Paraffin | 0.49 | 0.97 | 1.33 | 1.63 |
| | None | 1.15 | 2.30 | 3.21 | 4.37 |
| 28° | Paraffin | — | 0.32 | 0.68 | 1.02 |
| | None | 0.83 | 1.32 | 1.71 | 2.19 |

* Stored in boxes at approximately two weeks of age; 16 flats were stored at each temperature, 8 were paraffined, 8 were not.

TABLE 20:10. MOISTURE LOST BY YOUNG AMERICANS* IN STORAGE (Lane, 1906)

| Storage temperature | Treatment | Moisture lost by 100 pounds of cheese | | | |
|---|---|---|---|---|---|
| | | 49 days storage | 112 days storage | 171 days storage | 233 days storage |
| °F. | | lb. | lb. | lb. | lb. |
| 40° | Paraffin | — | 0.60 | 2.00 | 2.38 |
| | None | 2.37 | 4.73 | 6.81 | 9.34 |
| 34° | Paraffin | 0.59 | 1.18 | 1.58 | 2.11 |
| | None | 1.21 | 3.03 | 5.02 | 6.95 |
| 28° | Paraffin | — | 0.60 | 1.17 | 1.45 |
| | None | 0.61 | 1.82 | 2.83 | 4.25 |

* Stored in boxes at approximately two weeks of age; 12 Y.A.'s were stored at each temperature, 6 were paraffined, 6 were not.

Tables 20:8, 20:9, and 20:10 show the results of his trials with three different styles of cheese. The greatest amounts of moisture were saved by paraffining cheese to be stored at the higher temperatures. Paraffining was relatively most effective when applied to the Young American style. At the end of eight months of storage the paraffined cheddars had lost 3.19 per cent of their into-storage weight at 40°F., 1.36 per cent at 34°F., and 1.27 per cent at 28°F. At the same temperatures of 40°, 34°, and 28°F. the non-paraffined cheddars had lost 5.87, 5.12 and 2.88 per cents respectively, of their weights into storage. Such differences can perhaps be more readily appreciated by multiplying these savings in pounds of cheese by the value of cheese per pound.

The effects of paraffining on moisture losses are illustrated by the curves in figure 20:2. These curves do not show rapid losses of moisture during the first month of storage, like the curves of figure 20:1, because these cheddars studied by Lane were purchased and stored at approximately two weeks of age; the losses of moisture that occurred during this first two-week interval after making were unknown to Lane. The losses of moisture from the non-paraffined cheddars held at 40°F. were almost continuously over twice the losses experienced by the paraffined lots of identical cheese. Losses of non-paraffined cheddars held at 34°F. showed three to six times the losses of identical lots paraffined and held at the same temperature.

**Time of paraffining and shrinkage.** The curves of figure 20:1 show that losses in moisture during the first few days after making are greater than during any other similar period in the life of the cheese. The extent of the losses before paraffining influences the amount of shrinkage which occurs after paraffining. Doane (1911) measured the influence of time of paraffining on shrinkage by dividing each of four vat lots of cheese into three groups. The first group he paraffined as the cheese came from the press; the second, at three days of age; and the third, at seven days of age. These lots of cheese, which were all of the daisy style, were then stored at 35°F., presumably in boxes. The average weights of the daisies when paraffined were 21.81, 21.44 and 21.06 pounds for the groups paraffined at the press, three days, and seven days, respectively. After curing for 5 months, the daisies of these same groups, named in the same order, averaged in weight: 21.31, 21.28, and 20.97 pounds. More cheese was available for sale in the group paraffined directly from the press, but unfortunately the keeping properties in storage were not as good as those of the cheese paraffined at three days of age. Actual shrinkage during the storage period averaged 0.50, 0.16, and 0.09 pounds per daisy for the three groups which are still listed in the same order in which they were named above.

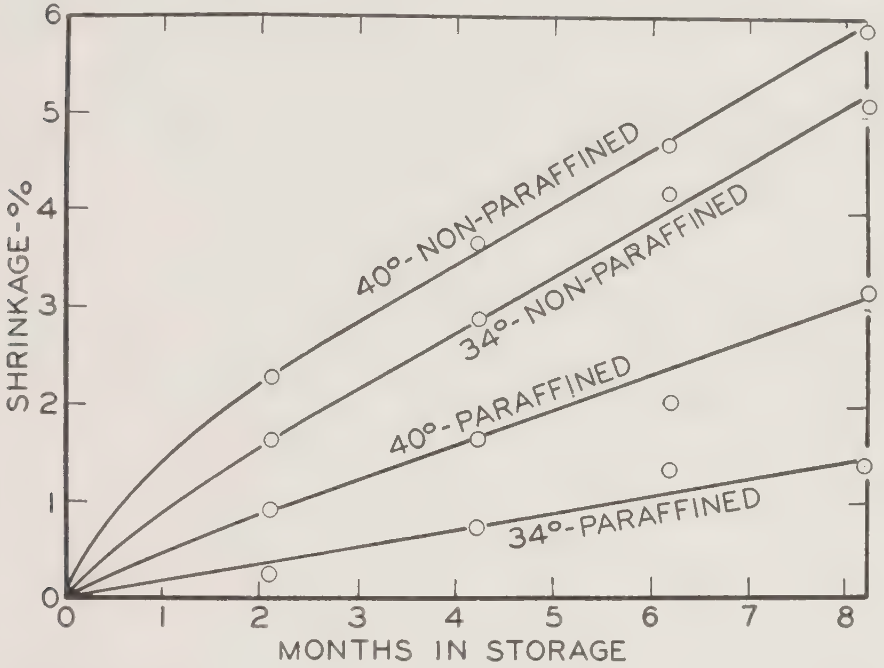


Figure 20:2. Losses of weight by cheese in storage are fairly constant after 4 to 8 weeks. Losses are minimized by holding paraffined cheese at low temperatures. The data were collected by Lane (1906) on cheddars stored in boxes at two weeks of age.

Sammis and Bruhn (1912) measured the shrinkage in cheese made from pasteurized, acidulated milk. The cheese were paraffined at different ages and stored at different intervals. The temperatures at which the cheese were held before storage were 60° to 70°F.; storage was at 34°F. The lots that were paraffined within a few days after making, and then stored immediately, experienced the least total shrinkage, approximately 2% before and 1% after storage. The daisies which were paraffined at 10 days of age and then held an additional 18 days before storage showed the greatest shrinkage; approximately 6% of the weight was lost before storage and 2% after storage. Losses in storage were not greatly different for the several treatments; they were always less than the losses before storage. The data of these experiments are summarized in table 20:11.

TABLE 20:11. SHRINKAGE OF PASTEURIZED-MILK CHEESE
(Data from Sammis and Bruhn, 1912)

| *Number of daisies* | *Age at paraffining* | *Age at storing* | *Average days in storage* * | *Shrinkage of 100 pounds of green cheese* ** | |
|---|---|---|---|---|---|
| | | | | *Before storing* | *In storage* |
| | *days* | *days* | *days* | *lb.* | *lb.* |
| 7 | 1 | 1 | 89 | 2.08 | 1.14 |
| 7 | 7 | 7 | 89 | 4.35 | .75 |
| 7 | 10 | 14 | 89 | 5.25 | 1.23 |
| 8 | 10 | 28 | 90 | 6.32 | 1.95 |

* Minimum days in storage 67, maximum 100.

** Temperature until placed in storage, 60°—70°F.; storage temperature, 34°F.

The type of paraffin used affects the shrinkage of the cheese in storage. Reichart and Downs (1941) studied the influence of paraffin, wax, and Parafilm on the curing of five-pound prints of Cheddar. Their study is significant because the use of mixtures of paraffin and microcrystalline wax is becoming more common. These mixtures in the cheese industry are simply called **wax**. The wax has greater flexibility than the paraffin which has been used for so many years for coating cheese. **Parafilm** is the trade name of a patented product of the Marathon Corporation; it has high moisture proofness and flexibility and has only been used for wrapping small square styles of cheese. The effects of these coverings on shrinkage of cheese held at 45°F. and 65°F. are shown in table 20:12. During nine months of storage at 45°F., losses ranged from a maximum of 12.12% for paraffined cheese to 0.63% for the black Parafilm wrapper;

waxed cheese lost 6.48% of its original weight. The losses in storage at 65°F. were definitely higher.

TABLE 20:12. SHRINKAGE OF 5-POUND PRINTS OF CHEDDAR CHEESE DURING STORAGE FOR 9 MONTHS

(Reichart and Downs, 1941)

| *Types of covering* | *No. of lots* | *Moisture lost by 100 pounds* | |
|---|---|---|---|
| | | *45°F. storage* | *65°F. storage* |
| | | *lb.* | *lb.* |
| Paraffin | 5 | 12.42 | 16.23 |
| Wax | 5 | 6.48 | 9.77 |
| White Parafilm | 5 | 1.19 | 8.69 |
| Black Parafilm | 5 | 0.63 | 3.44 |

**Moisture in cheese and shrinkage.** McDowall (1936) reported the shrinkage rates on several hundred lots of cheddars during the first 14 days of curing. He classified these losses according to the moisture content of the cheese after the 14 day holding period. He demonstrated that there was a definite in-

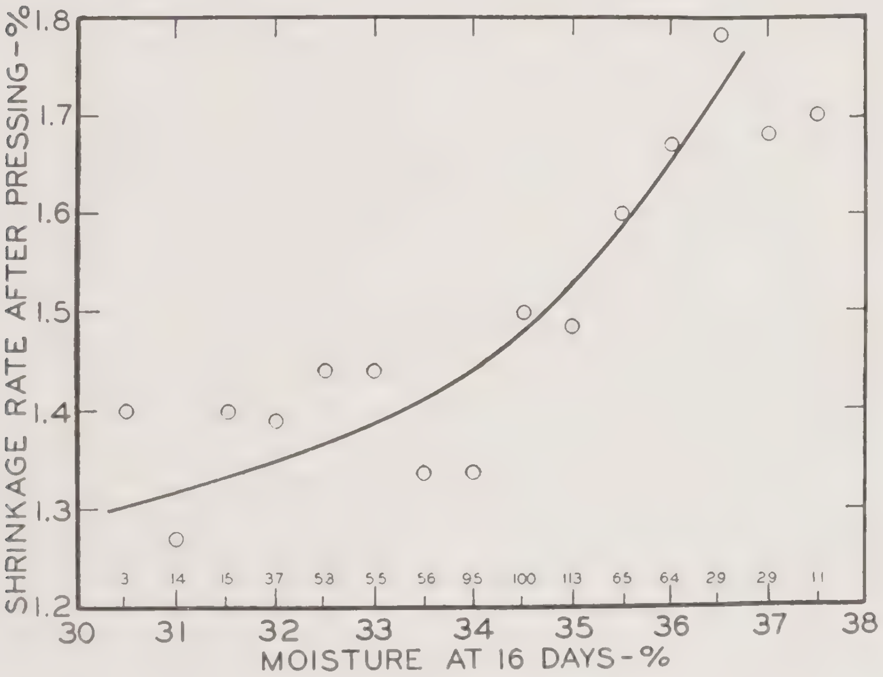


Figure 20:3. The shrinkage rate after pressing increases as the moisture content of the cheese increases. McDowall (1936) reported these data on per cent of weight lost by 739 cheddars during the first 14 days after pressing. The small figures inside the frame at the bottom of the graph are the numbers of cheddars in each moisture class.

crease in shrinkage in lots with higher moisture contents. These data have been plotted in figure 20:3. The trends of the observations were somewhat irregular and McDowall suggested that they should be interpreted with some reserve because of variations caused by factors beyond his control.

Additional evidence on this relation is available in the work of Babcock, Russell and Baer (1903). They selected three types of Cheddar cheese which they classified as: firm-bodied; sweet-curd type; and very moist, soft type. Time in transit from factory to storage varied from 5 to 17 days. At 90 days of age the firm-bodied cheese had lost 1.0% of its into-storage weight; the soft-bodied cheese had lost 1.2%; and the sweet-curd type, 1.4%. A summary of the losses during the first 90 days of storage is presented in table 20:13.

TABLE 20:13. WEIGHT LOST BY DIFFERENT TYPES NON-PARAFFINED, FLAT-STYLE CHEDDAR CHEESE WHEN STORED IN BOXES
(Babcock, Russell and Baer, 1903)

| *Storage period* | *Moisture lost by 100 pounds of cheese at 40°F.* | | |
|---|---|---|---|
| | *Firm-bodied* | *Soft-bodied* | *Sweet-curd type* |
| *days* | % | % | % |
| 10 | 0.38 | 0.49 | 0.69 |
| 20 | 0.44 | 0.64 | 0.82 |
| 30 | 0.58 | 0.84 | 0.96 |
| 60 | 0.83 | 0.98 | 1.15 |
| 90 | 1.00 | 1.21 | 1.42 |
| Number of cheese | 27 | 30 | 9 |

**Texture of cheese and shrinkage.** The sweet-curd type of cheese tends to be open in texture. This is caused in part by the greater production of carbon dioxide in the curing process. Such cheese presents greater surface area per unit weight. The openness of the cheese facilitates the diffusion of moisture through the cheese. Unusual losses in weight by such cheese during storage must therefore be expected. The data of table 20:13 show how such losses compare with those of firm-bodied, close-textured Cheddar cheese.

## REFERENCES

Babcock, S. M., Russell, H. L. and Baer, U. S. (1903). Wis. Agr. Expt. Sta., Bul. 101.
Doane, C. F. (1911). U. S. Dept. Agr., Bur. An. Ind., Circ. 181.
Dorn, F. L. and Dahlberg, A. C. (1942). J. Dairy Sci., 25, 31.

Golding, N. S. (1944). J. Dairy Sci., *27*, 679.
Lane, Clarence B. (1906). U. S. Dept. Agr., Bur. An. Ind., Bul. 83.
McDowall, F. H. (1936). Dept. Sci. and Ind. Res., Bul. 50.
Reichart, E. L. and Downs, P. A. (1941). J. Dairy Sci., *24*, 19.
Sammis, J. L. and Bruhn, A. T. (1912). Wis. Agr. Expt. Sta., Res. Bul. 27.
Tretsven, Wayne I. (1945). Thesis. University of Wisconsin.
Van Slyke, L. L. (1901). N. Y. (Geneva) Agr. Expt. Sta., Bul. 207.
Van Slyke, L. L. and Hart, E. B. (1903). N. Y. (Geneva) Agr. Expt. Sta., Bul. 231.
Van Slyke, L. L., Smith, G. A. and Hart, E. B. (1903). N. Y. (Geneva) Agr. Expt. Sta., Bul. 234.

## CHAPTER 21

# CHANGES DURING THE RIPENING OF CHEDDAR CHEESE

The ripening of Cheddar cheese is a complex process which has never been fully explained. It has been studied by chemists and bacteriologists for many years and is still the subject of scientific investigation.

### RIPENING AGENTS

Bacteriologists have associated groups of organisms with the various stages of ripening. The discussions of Chapter 7 called attention to these groups of microorganisms. Chemists have studied the relationship of changes in the constituents of cheese to the development of the properties of the ripened cheese. These bacteriological and chemical studies indicate that the characteristic properties of ripened cheese must be attributed to the actions of several types of bacteria and enzymes. It seems logical to assume that these organisms and enzymes are interdependent. The products formed by these biological agents in the making process and in the early stages of ripening are undoubtedly essential for the successive actions of other biological agents, either enzymes or microorganisms, or both, in the later stages of curing.

The sources of the biological agents in cheese can be controlled only in part by the maker. Milk and starters contribute the major portion of the bacterial content of cheese. Rennet extract introduces the milk coagulating and protein digesting enzymes, rennin and pepsin. It has been assumed that milk enzymes might be extremely important in the curing of cheese. Recent work by Peterson, et al. (1948, 1948a) would seem to indicate that the lipases and proteases of cheese are elaborated by bacteria during the ripening processes.

### RIPENED CHEESE

Ripened cheese differs from fresh cheese in flavor and consistency.

**Flavor.** The characteristic flavor of ripened Cheddar cheese is really a blend of several odors and tastes. These sensations are derived from volatile and soluble substances. Thoughtful and careful consideration of the sensations of tasting and smelling Cheddar cheese reveals various outstanding fractions. The taste buds in the mouth detect a slightly salty sensation. Taste and smell reveal the mild, acid flavor that is characteristic of Cheddar cheese. In mild cheese the odor of diacetyl is faintly present (Calbert and Price, 1948). In well aged cheese several odoriferous fractions are apparent including: traces of odors of butyric and caproic acids; aromatic fractions resembling the odors of esters of alcohol and salts of propionic and acetic acids; and, in very old cheese, the pungent odors of compounds of ammonia and sometimes hydrogen sulfide.

Changes in kind and intensity of flavors continue as long as the cheese is held under ripening conditions. This is to be expected because the activities of microorganisms and the enzymes produced by them never wholly cease under such conditions. Amino acids can be measured in increasing amounts as the cheese ages. Harper and Swanson (1948) believe that these products may either cause or be associated with the development of cheese flavor.

**Body.** The consistency of ripening cheese changes rapidly during the first few weeks after making. The curdiness of the fresh product disappears in a period of two to four weeks when the normal cheese is held at 45°F. This change is associated primarily with the protein of the cheese. The combined effects of acidity, moisture, salt, rennet, and bacterial action influence the rate of these chemical and physical changes. Prolonged curing of cheese usually permits loss of moisture so that the cheese becomes more firm. At the same time the cheese loses some of its original plasticity or waxy properties and tends to be brittle or even crumbly. This last change in physical properties can be attributed in part to loss of moisture and in part to the chemical changes in the protein brought about by the continued digestive actions of microorganisms and enzymes.

## CHEMICAL CHANGES IN RIPENING CHEDDAR CHEESE

The principal chemical compounds in fresh Cheddar cheese are the same compounds and groups of compounds that normally occur in milk. The common salt used in making the cheese is the chief new substance added. These compounds include: water, proteins, fat, lactose, salts, pigments, vitamins, and gases.

The changes in some of the compounds of unripe cheese have been studied to determine their relation to the characteristics of the ripened product.

**Water.** The water in cheese is necessary for the activities of the biological agents of ripening. Some of it gradually evaporates from the cheese during ripening. Some of it becomes more intimately associated with the proteins as ripening progresses. This association may be of either a physical or chemical nature.

**Proteins.** It is desirable to call attention to some of the properties of proteins with which the study of the ripening of cheese is concerned. Casein, like other natural proteins, is made up of a combination of compounds known as amino acids. Amino acids are the unit structures from which proteins are constructed; they are often likened to building stones. When casein undergoes decomposition in the process of cheese ripening, it breaks up first into large aggregates or groups of combined amino acids; these aggregates have been given the general name of proteoses, or sometimes caseoses, since they are derived from casein. On further decomposition, these aggregates are changed into smaller groups of amino acids, called peptones. Finally, the peptones, if they are still further disintegrated, may yield the individual amino acids.

These divisions of substances derived from the original proteins are rather arbitrarily based upon their solubility in water, coagulability by heat, and upon precipitation from their water solutions by different salts and acids. Estimates of the amounts of these decomposition products in cheese are used as indications of the extent of ripening.

The development of these protein decomposition products are not directly related to the quality of the cheese. Cheese made from raw milk or from milk of inferior quality tends to undergo protein decomposition more rapidly than cheese made from pasteurized milk or milk of superior quality. The quality of cheese made from inferior milk is consistently less desirable than that made from milk of high quality.

The extensive decomposition of the protein in cheese begins when the rennet extract is added to the milk. The enzyme rennin in the rennet extract hydrolyzes calcium caseinate to calcium paracaseinate. This new compound is insoluble in water and in warm 5 per cent solution of sodium chloride.

The development of lactic acid in the curd and fresh cheese causes the second major change in the protein of the cheese. Some of the calcium of the calcium paracaseinate is removed by the action of the acid. Van Slyke and Bosworth (1913) named the new protein fraction thus formed, **mono-calcium paracaseinate.** The reactions that result in the formation of this compound are complicated; the essential ideas, however, might be indicated as follows:

(1) Calcium caseinate + rennin → calcium paracaseinate
(2) Calcium paracaseinate + lactic acid →
mono-calcium paracaseinate + calcium lactate.

In the first reaction, the compound of special interest is the calcium paracaseinate which is precipitated in the presence of soluble calcium salts.

In the second reaction, which takes place during curd making and shortly thereafter, the calcium paracaseinate undergoes some very marked changes. These changes can be observed in one of the physical-chemical properties of the cheese; the curd becomes increasingly soluble in warm (123° to 132°F.) 5 per cent solution of common salt in water. Van Slyke and Bosworth (1907) reported that this change takes place very rapidly. Typical observations from their work are shown in table 21:1. They believed that the brine soluble mono-calcium paracaseinate was the protein from which the microorganisms and enzymes in the ripening cheese eventually produced caseoses, peptones, amino acids, and ammonia.

TABLE 21:1. CHANGES IN SOLUBILITY OF PROTEINS IN CHEDDAR CHEESE

(Van Slyke and Bosworth, 1907)

| *Age of cheese* * | *Percentage of protein soluble in 5 per cent salt solution* | *Percentage of protein soluble in water* |
|---|---|---|
| | % | % |
| At dipping | 4.50 | — |
| At pressing | 30.15 | 3.77 |
| 2 hours | 46.46 | 4.25 |
| 9.5 " | 96.06 | 6.48 |
| 21.5 " | 85.22 | 6.09 |
| 2 days | 68.87 | 4.75 |
| 7 " | 43.80 | 8.26 |
| 30 " | 46.79 | 16.84 |
| 90 " | 42.78 | 25.34 |

* Age of cheese calculated from time of pressing.

It is possible that some of the final derivatives of the monocalcium paracaseinate contribute to the characteristic flavor of the ripened cheese. This assumption is not unlikely because: only minute quantities of flavorful substances are necessary to be detected by taste and smell; some of these protein derivatives have distinctive flavors; and the full flavor of ripened cheese does not appear until these simpler derivatives of protein decomposition can be found in the cheese by analyses. These derivatives are formed more slowly and in smaller amounts in cold-cured cheese, hence the mild flavor of such cheese. Cheese with pungent odor and biting taste usually contains ammonia in larger amounts than cheese with mild flavor. When bacterial action is prevented by antiseptics or sterilization, neither the flavor nor the simpler protein derivatives are formed in the cheese.

**Fat.** The fat in Cheddar cheese probably undergoes slight chemical changes during ripening. Suzuki, Hastings and Hart (1910) observed the presence of esters of butyric and caproic acids in highly flavored, low-fat Cheddar. They believed that these esters originated partly in the fats.

Lane and Hammer (1939, 1939a, 1941) indicated that lipolytic changes in fat were important in producing Cheddar flavor. Measurements of the alkali-combining capacity of the fat tended to increase with increasing flavor. Tuckey (1941) also observed that changes in the acidity of the fat indicated fat hydrolysis. Babel and Hammer (1945) showed that the acidity of the fat increased with the age of the cheese.

Research workers in England in recent years have been particularly interested in the development and sources of volatile acidity in cheese. The trends of their findings were probably expressed by Hiscox (1941) when she pointed out that volatile acids developed in cheese from enzyme action on fat and lactose, and that, while fat lipolysis was slight, it was a very important factor in the production of flavor in Cheddar cheese.

The odor components of the flavor of Cheddar cheese definitely suggest the presence of some of the fatty acids of lower molecular weights. It seems highly probable that some limited amount of fat hydrolysis in the normal ripening of Cheddar cheese is responsible for these odors.

**Lactose.** The milk sugar in unripened cheese is quickly used by the microorganisms present. Lactic acid is the principal product of this fermentation but smaller amounts of other acids are formed. Van Slyke and Bosworth (1907) presented analyses showing that lactose disappeared very rapidly in the early life of Cheddar cheese; only a trace remained, if any at all, after 2 weeks. Typical data are shown in table 21:2. McDowall and Dolby (1936) reported analyses for lactose in Cheddar that agreed very well with the data in table 21:2.

TABLE 21:2. DISAPPEARANCE OF MILK SUGAR IN CHEDDAR CHEESE IN THE FIRST TWO WEEKS AFTER MAKING

(Van Slyke and Bosworth, 1907)

| *Age of cheese* | *Sample 1* | *Sample 2* | *Sample 3* |
|---|---|---|---|
| | % | % | % |
| 0 hours (pressing) | 1.70 | 0.77 | 1.52 |
| 3 " | 1.05 | 0.68 | 0.64 |
| 6 " | 0.68 | 0.44 | — |
| 12 " | 0.68 | — | 0.80 |
| 2 days | 0.58 | 0.10 | 0.36 |
| 4 " | 0.50 | 0.04 | 0.32 |
| 7 " | 0.10 | 0.03 | 0.22 |
| 14 " | 0.07 | 0.00 | trace |

Suzuki, Hastings and Hart (1910) observed that the lactose disappeared from the fresh cheese in 3 to 6 days. The lactates thus formed were converted in part by microorganisms to acetic and propionic acids. Hiscox, Harrison, and Wolf (1941) found that the acetic acid derived from the lactose constituted the bulk of the volatile acidity of cheese. Hiscox (1941) pointed out that production of volatile acids in cheese tended to parallel flavor production. Dahlberg and Kosikowsky (1947) on the other hand, found no relation between intensity of flavor and total volatile acidity of Cheddar cheese. Dahlberg and Kosikowsky (1948) later reported data showing a general trend between increasing intensity of Cheddar cheese flavor and the presence of large amounts of volatile acids despite the fact that individual samples sometimes failed to conform to this trend.

Calbert and Price (1948) called attention to the probable contribution of diacetyl to the flavor of Cheddar cheese. The lactose is the chief substance from which this flavorful compound is formed.

It seems certain that the typical flavor of ripened Cheddar cheese is directly affected by end products of lactose fermentation. The initial conversion of the lactose to lactic acid in the first few days of curing creates a background of character to the cheese flavor which endures as long as the cheese is edible.

**Milk salts.** The changes in the salts of milk during the ripening of cheese are very complex; little or nothing is actually known about them. Yet it seems highly probable that some of the compounds which are formed impart characteristic tastes and odors to ripened cheese.

The important milk salts in fresh cheese include chlorides, citrates, phosphates, and lactates of calcium, magnesium, potassium, and sodium. The amounts of the soluble salts held in the cheese depend upon the amount of moisture retained by the curd and by the acid developed in the making process. During ripening these salts are modified by evaporation of moisture, changes in acidity, and by the formation of products of decomposition of fats and proteins. The electrolytic dissociation theory explains why the changes in milk salts during ripening are so extremely complicated.

McCammon, Caulfield and Kramer (1933) found that 80 per cent of the calcium of the milk and 38 per cent of the phosphorus were retained in Cheddar cheese. McDowall and Dolby (1935) stated that 60 per cent of the calcium and 57 per cent of the phosphorus of milk were retained in normal cheese. These proportions, they found, were influenced by the acidity development during the manufacturing operations. Zahrndt, Lane and Hammer (1944) found an average of 1.14 per cent calcium and 0.78 per cent phosphorus in the dry matter of 52 samples of Cheddar cheese; they called attention to the marked uniformity of the observations. Irvine, et al. (1945, 1945a) reported the retention of 61 per cent of the calcium and 53 per cent of the phosphorus of milk in Cheddar cheese made from raw milk. They found that pasteurization of milk did not affect the retention of calcium and tended to increase slightly the retention of phosphorus in the cheese.

White specks or particles are commonly formed in Cheddar cheese which is cured at low temperatures. These particles have no distinct taste or odor. They were noticed and studied, but were not identified, when cold curing of cheese was first being investigated (Babcock, et al., 1902). Van Slyke believed they were a combination of calcium and some fatty acid derived from fat by the action of microorganisms. Tuckey, Ruehe and Clark (1938) used X-ray analyses and decided that these specks were calcium lactate. McDowall and McDowell (1939) picked the specks out of cheese, analyzed them, and found 28.5 per cent moisture, 11.3 per cent protein, 17.2 per cent fat, and 42.5 per cent calcium lactate. The non-lactate portion of the white particles, they believed, consisted of cheese adhering to the specks. Dorn and Dahlberg (1942) found that the crystal structure, the chemical reactions, and the chemical composition of the white crystalline material were typical of tyrosine, an amino acid.

It seems probable that the differences in the findings of these several workers may be explained by the nature of the cheese used as source material, by methods of analysis, and by the methods of collecting the material for analysis. More work is needed to clarify these explanations of the identity of the white specks in Cheddar cheese.

**Pigments.** The pigments of milk retained in the cheese apparently do not undergo any extensive changes during the ripening process. The fat-soluble carotene and the water-soluble riboflavin are found in the curd and in the cheese in proportion to the division of the milk constituents in the making process. It is possible that these pigments may play an important part in the metabolisms of some of the microorganisms in the ripening cheese.

**Vitamins.** The vitamins of milk retained in cheese probably do not change materially during the curing process. Guerrant, Dutcher and Dahle (1938) observed no serious destruction of vitamin A during the aging of cheese. Davies and Moore (1939) found vitamin A potency in cheese to be of an order that would be expected from the fat content of the milk. Higuchi, Price, and Peterson (1946) found that the distribution of vitamin A potency in cheese making was 85 per cent to the cheese, 7 per cent to the whey, and 8 per cent unaccounted for. Vitamin A potency of Cheddar cheese during ripening and storage remained practically unchanged over almost one year, as shown in table 21:3. Higuchi and Peterson (1946) analyzed over 500 samples of cheese, principally Cheddar and Swiss. They found that vitamin A potency of the cheese varied with the season;

TABLE 21:3. CHANGES IN CAROTENE AND VITAMIN A CONTENT OF CHEDDAR CHEESE IN STORAGE

(Higuchi, Price, and Peterson, 1946)

| *Lot* | *Carotene content after* | | | | *Vitamin A content after* | | | |
|---|---|---|---|---|---|---|---|---|
| | *0 wks.* | *8 wks.* | *12 wks.* | *42 wks.* | *0 wks.* | *8 wks.* | *12 wks.* | *42 wks.* |
| | *micrograms per gram* | | | | *micrograms per gram* | | | |
| I | 1.37 | 1.36 | 1.40 | 1.44 | 1.87 | 1.86 | 1.86 | 1.85 |
| II | 1.55 | 1.66 | 1.67 | 1.72 | 1.98 | 1.98 | 1.98 | 1.97 |
| III | 1.50 | 1.62 | 1.63 | 1.67 | 2.21 | 2.24 | 2.28 | 2.26 |

Each value represents the average of 8 samples.

it was highest in cheese made in late summer and early fall and lowest in late winter and early spring. Average Cheddar values ranged from 7900 International Units (I. U.) per pound in fall to 3600 I. U. per pound in spring.

Daniel and Norris (1941) found that Cheddar cheese contained 3 micrograms of riboflavin per gram of cheese. Irvine, et al. (1945, 1945a) observed some loss of riboflavin during manufacturing; approximately 23 per cent of the riboflavin in the milk was retained in the cheese. Riboflavin values declined during the first two months of curing but later returned to the values observed in the fresh cheese. Pasteurization of the milk did not affect the amount or stability of riboflavin during ripening.

**Gases.** The gases of milk which may be carried into the ripening cheese are of no known significance in the curing of the cheese.

## METHODS OF MEASURING RIPENING PROGRESS

**Judging.** The nature of the chemical changes in cheese ripening that have just been considered suggest various ways of measuring such changes. The most practical method is to examine the cheese for changes in flavor, body, texture, color and appearance. This is the technique used in merchandising cheese. Expert judges can readily evaluate the ripening changes in terms of consumer satisfaction.

**Biological, chemical, and physical measurements.** Bacteriologists, chemists and physicists prefer to apply measurements which are determined by the object rather than by the mind of the judge. Consequently, biological, chemical, and physical measurements of the changes in cheese during ripening have been used as indications of the rate of ripening. Examples of such measurements are: changes in enzyme content and in numbers and types of organisms present in the cheese; changes in moisture, lactose content, acidity of fat, pH, volatile acidity, oxidation-reduction potential, salt distribution, and protein degradation; changes in firmness, plasticity, elasticity, gas production, and freezing point.

**Protein changes.** The measurement that has been used most systematically and extensively in studying the ripening of cheese is that of protein degradation. These measurements are made to determine the rate at which the insoluble, complex proteins of the curd are changed into the water-soluble, simpler forms. Sometimes this information alone is adequate but sometimes identification and measurement of the amounts of caseoses, peptones and amino acids are desirable. Protein degradation has been used to study the relation to ripening of such factors as time, temperature, moisture in the cheese, size of cheese, salt content, rennet, and pasteurization of the milk. Results of a few of many studies are presented to illustrate the effectiveness of these various factors on the ripening of Cheddar cheese in terms of formation of protein derivatives. The methods of analysis used in obtaining these data were described essentially by Van Slyke and Hart (1902).

## IMPORTANT FACTORS AFFECTING RATE OF CHEESE RIPENING

**Time.** Under normal conditions of ripening there is a progressive increase of water-soluble, protein-derived substances. Van Slyke and Hart (1903) analyzed 24 different samples of Cheddar cheese to obtain the data of table 21:4.

TABLE 21:4. EFFECT OF TIME OF CHEESE RIPENING ON CHANGES IN PROTEINS
(Van Slyke and Hart, 1903)

| | *Nitrogen, expressed as percentage of nitrogen in cheese, in form of:* | | | | |
|---|---|---|---|---|---|
| *Age of cheese* | *Mono-calcium paracaseinate* | *Water-soluble derivatives from paracasein* | *Caseoses and peptones* | *Amino acids* | *Ammonia* |
| *months* | % | % | % | % | % |
| 1½ | 20.18 | 21.44 | 7.00 | 9.90 | 1.56 |
| 3 | 27.26 | 31.00 | 9.20 | 14.35 | 2.45 |
| 6 | 27.55 | 36.15 | 9.15 | 20.00 | 3.52 |
| 9 | 24.14 | 43.45 | 8.15 | 26.50 | 4.74 |
| 12 | 19.04 | 44.75 | 8.10 | 28.40 | 5.41 |

The averages in table 21:4 indicate that there was a continual increase in water-soluble, protein derivatives throughout ripening. Production of amino acids and ammonia followed the same trend. Nitrogenous compounds in the form of mono-calcium paracaseinate, caseoses and peptones tended to increase and then decrease during cheese ripening. The rate of formation of the water-soluble compounds was more rapid in the early stages of ripening; about two-thirds of these compounds were formed in the first 3 months and over 90 per cent in the first 9 months.

Van Slyke, Smith and Hart (1903) studied the curing of Cheddar cheese on the commercial scale in cooperation with the United States Department of Agriculture. Nine lots of cheese were stored at 40°F. Analyses showing protein changes of these lots are presented in table 21:5.

TABLE 21:5. EFFECT OF TIME OF CHEESE RIPENING ON CHANGES IN PROTEINS

(Van Slyke, Smith, and Hart, 1903)

| *Form of proteins and derivatives* * | *Weeks of ripening at 40°F.* | | | | |
|---|---|---|---|---|---|
| | *1* | *10* | *20* | *28* | *35* |
| | % | % | % | % | % |
| Paracasein monolactate | 57.49 | 47.94 | 47.10 | 40.54 | 36.36 |
| Total water-soluble | 14.55 | 20.03 | 21.12 | 26.27 | 27.64 |
| Amido compounds | 4.06 | 6.92 | 5.53 | 7.60 | 9.00 |
| Ammonia | 0.00 | 1.20 | 1.62 | 2.52 | – |

* Amounts are expressed as percentages of the nitrogen in cheese.

Paracasein monolactate was later identified by Van Slyke and Bosworth (1913) as mono-calcium paracaseinate.

TABLE 21:6. EFFECT OF TEMPERATURE OF CHEESE RIPENING ON CHANGES IN PROTEINS

(Van Slyke and Hart, 1903)

| *Forms of proteins and derivatives* | *Temperature of curing-room* | *Nitrogen expressed as percentage of nitrogen in cheese* | | | | |
|---|---|---|---|---|---|---|
| | | *1½ mos.* | *3 mos.* | *6 mos.* | *9 mos.* | *12 mos.* |
| Total water-soluble | *Deg. F.* | % | % | % | % | % |
| | 32 | 12.80 | 18.64 | 23.06 | 32.66 | 34.02 |
| | 55 | 20.56 | 31.46 | 36.09 | 43.91 | 45.09 |
| | 60 | 23.14 | 33.69 | 39.97 | 46.89 | 48.62 |
| | 70 | 29.24 | 40.13 | 45.50 | 50.34 | 51.25 |
| Mono-calcium paracaseinate | 32 | 20.58 | 43.14 | 36.55 | 43.00 | 34.48 |
| | 55 | 33.01 | 33.66 | 35.10 | 25.61 | 19.26 |
| | 60 | 13.89 | 18.81 | 19.94 | 16.15 | 12.32 |
| | 70 | 13.24 | 13.45 | 18.62 | 11.83 | 10.10 |
| Caseoses and peptones | 32 | 2.35 | 5.20 | 9.77 | 8.65 | 8.70 |
| | 55 | 8.00 | 9.45 | 9.00 | 8.86 | 8.45 |
| | 60 | 6.75 | 12.13 | 10.73 | 8.50 | 7.70 |
| | 70 | 10.85 | 10.10 | 7.04 | 7.57 | 7.63 |
| Amino acids | 32 | 4.82 | 6.36 | 8.70 | 17.55 | 18.73 |
| | 55 | 8.69 | 14.33 | 19.55 | 27.05 | 29.00 |
| | 60 | 12.16 | 14.55 | 21.39 | 28.84 | 31.14 |
| | 70 | 13.86 | 22.20 | 30.80 | 32.68 | 34.65 |
| Ammonia | 32 | 0.61 | 0.61 | 1.21 | 1.91 | 2.14 |
| | 55 | 1.50 | 2.42 | 3.30 | 4.69 | 5.57 |
| | 60 | 1.67 | 2.51 | 3.89 | 5.43 | 6.12 |
| | 70 | 2.47 | 4.22 | 5.71 | 6.91 | 7.49 |

The percentages of the nitrogen of the cheese in the form of protein derivatives were generally lower in this series of experiments than in the series reported in table 21:4. This can be explained by differences in the composition of the cheese and in storage temperatures. The trends of changes illustrated in tables 21:4 and 21:5 seem to be essentially the same.

**Temperature.** Temperature exerts a marked influence on ripening. Table 21:6 illustrates the effect of temperature on the protein degradation of cheese held at 32°, 55°, 60°, and 70°F. Four different cheese were analyzed at each temperature and the results were averaged.

The data of table 21:6 show that: 1) the water-soluble, protein derivatives increased very closely in proportion to increase of temperature; 2) there was an average increase of 0.5 per cent of these water-soluble compounds for an increase of 1 degree of temperature between the limits of 32° and 70°F.; and 3) the amino acids and ammonia were formed in the cheese more abundantly at higher temperatures and accumulated there. The other water-soluble compounds did not appear to be regularly influenced by temperature in the early stages of ripening, but after some months they decreased in quantity with increase of temperature.

Van Slyke, Smith and Hart (1903) studied the effects of temperature on the changes in the protein fractions of the cheese. Their data are shown in table 21:7. The trends emphasize a possible explanation of the accelerated curing effects which are apparent in the characteristics of cheese stored at high temperatures. These workers believed that it was significant that little or no cheese flavor appeared in the cheese until amido com-

TABLE 21:7. INCREASE* IN THE PERCENTAGE OF NITROGEN IN THE FORM OF PROTEIN DERIVATIVES: THE RIPENING PERIOD, 20 WEEKS

(Van Slyke, Smith and Hart, 1903)

| *Form of proteins and derivatives* | *Temperature of ripening* | | |
|---|---|---|---|
| | *40°F.* | *50°F.* | *60°F.* |
| | % | % | % |
| Total water soluble | 9.57 | 17.01 | 21.69 |
| Amido compounds | 1.47 | 4.89 | 9.24 |
| Ammonia | 1.62 | 2.44 | 3.36 |

* The increase is expressed as percentage of nitrogen in the cheese and is the difference between measurements made at one week and 20 weeks of age.

pounds were present. They stated the possibility that among these compounds were substances which were responsible for part of the typical flavor of Cheddar cheese.

**Moisture.** Van Slyke and Hart (1903) studied the influence of moisture content on protein degradation in Cheddar cheese. They analyzed two sets of cheese consisting of four lots in each set. One lot was covered with paraffin in order to retain the moisture; the second lot was held without paraffin. These two sets of cheese were cured at 55°F. The averages of the various analyses are shown in table 21:8.

TABLE 21:8. EFFECT OF MOISTURE IN CHEESE ON PROTEIN CHANGES DURING RIPENING

(Van Slyke and Hart, 1903)

| *Form of proteins and derivatives* | *Lot ** | *Nitrogen expressed as percentage of nitrogen in cheese* | | | | | |
|---|---|---|---|---|---|---|---|
| | | *1½ mos.* | *3 mos.* | *6 mos.* | *9 mos.* | *12 mos.* | *18 mos* |
| | | % | % | % | % | % | % |
| Total water-soluble | N | 17.32 | 27.09 | 31.76 | 39.09 | 39.80 | 42.77 |
| | P | 17.14 | 27.40 | 36.41 | 46.59 | 54.52 | 56.76 |
| Mono-calcium paracaseinate | N | 24.89 | 41.59 | 35.43 | 28.81 | 21.70 | 13.72 |
| | P | 21.17 | 30.42 | 49.29 | 20.16 | 9.81 | 5.30 |
| Caseoses and peptones | N | 5.10 | 9.90 | 8.00 | 8.00 | 8.15 | 6.20 |
| | P | 8.10 | 8.45 | 11.60 | 9.10 | 8.75 | 7.90 |
| Amino acids | N | 7.50 | 9.79 | 16.00 | 21.65 | 22.89 | 26.73 |
| | P | 7.22 | 12.59 | 17.12 | 26.03 | 29.44 | 29.00 |
| Ammonia | N | 1.34 | 2.15 | 3.04 | 4.17 | 4.53 | 5.72 |
| | P | 0.98 | 1.99 | 4.26 | 6.52 | 8.27 | 12.16 |
| Water | N | 36.40 | 35.27 | 32.41 | 27.86 | 28.02 | 27.75 |
| | P | 35.96 | 35.00 | 33.37 | 33.24 | 32.66 | 32.10 |

* N = Not paraffined
P = Paraffined

The data of table 21:8 indicate that the presence of more moisture in the cheese was associated with the formation of larger amounts of water-soluble compounds. During the first 3 months of curing, when the moisture contents of both sets of cheese were approximately the same, the measurable changes were quite similar. During the next 15 months of curing the non-paraffined cheese with the lowered moisture content showed a decreased rate of protein degradation.

**Size of cheese.** The percentage of moisture lost by small styles of cheese during curing is frequently greater than that lost by the larger styles. It is natural to expect that a pronounced difference in moisture lost by the small styles should delay breakdown of their protein material. When the treatments of large and small styles of identical cheese are comparable and result in no essential differences in moisture content during the curing operation then the rates of protein degradation remain comparable. Such conditions can be attained in packaging small styles of cheese when heavy, wax coatings or water-proof wrappers are used.

TABLE 21:9. EFFECT OF SALT ON PROTEIN CHANGES IN CHEESE RIPENING

(Van Slyke and Hart, 1903)

| *Form of proteins and derivatives, etc.* | *Am't of salt used for 1000 lbs. of milk* | *Nitrogen expressed as percentage of nitrogen in cheese* | | | | |
|---|---|---|---|---|---|---|
| | | *1½ mos.* | *3 mos.* | *6 mos.* | *9 mos.* | *12 mos.* |
| | *Lbs.* | % | % | % | % | % |
| Total water soluble | 0 | 23.42 | 34.26 | 40.52 | 49.10 | 51.38 |
| | 1½ | 21.80 | 32.10 | 37.67 | 44.13 | 45.88 |
| | 2½ | 21.67 | 29.92 | 34.73 | 42.93 | 43.52 |
| | 5 | 18.84 | 27.70 | 31.70 | 37.64 | 38.19 |
| Mono-calcium paracaseinate | 0 | 17.33 | 27.06 | 23.27 | 21.82 | 16.75 |
| | 1½ | 20.86 | 28.43 | 26.16 | 22.38 | 17.98 |
| | 2½ | 21.81 | 24.47 | 28.30 | 23.54 | 18.04 |
| | 5 | 20.73 | 29.02 | 32.49 | 28.81 | 23.41 |
| Caseoses and peptones | 0 | 8.27 | 9.96 | 9.78 | 9.07 | 9.08 |
| | 1½ | 6.74 | 10.18 | 9.46 | 8.07 | 8.56 |
| | 2½ | 7.41 | 8.16 | 9.00 | 8.13 | 7.95 |
| | 5 | 5.66 | 8.56 | 8.32 | 7.33 | 6.86 |
| Amino acids | 0 | 10.22 | 15.86 | 22.18 | 28.89 | 32.19 |
| | 1½ | 10.46 | 14.77 | 20.13 | 27.31 | 29.33 |
| | 2½ | 9.78 | 13.83 | 19.20 | 26.72 | 27.61 |
| | 5 | 8.82 | 12.97 | 17.34 | 23.21 | 24.40 |
| Ammonia | 0 | 1.67 | 2.96 | 4.64 | 6.54 | 7.77 |
| | 1½ | 1.67 | 2.53 | 3.69 | 4.69 | 5.36 |
| | 2½ | 1.51 | 2.36 | 3.13 | 4.30 | 4.54 |
| | 5 | 1.41 | 2.03 | 2.64 | 3.43 | 3.61 |
| Per cent water in cheese | 0 | 39.27 | 38.22 | 35.60 | 35.22 | 34.09 |
| | 1½ | 36.66 | 35.60 | 33.50 | 32.62 | 31.61 |
| | 2½ | 35.69 | 34.43 | 32.31 | 31.54 | 30.99 |
| | 5 | 33.63 | 36.62 | 29.52 | 29.88 | 28.61 |
| Per cent salt in cheese | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1½ | 0.59 | 0.70 | 0.84 | 0.94 | 0.92 |
| | 2½ | 0.82 | 1.20 | 1.15 | 1.26 | 1.27 |
| | 5 | 1.29 | 1.50 | 1.62 | 1.87 | 1.83 |

**Salt content of cheese.** Van Slyke and Hart (1903) studied the influence on ripening of the amount of salt. Four different lots, each consisting of 4 cheese, were made as nearly alike as possible. One cheese in each lot received no salt; the remaining 3 were salted at the rates of 1.5, 2.5, and 5 pounds of salt for 1000 pounds of milk. One lot of 4 cheese was cured at 32°, the others were cured at 55°, 60° and 70°F. The average of the analyses of the 4 lots are shown in table 21:9.

Table 21:9 shows that the amount of salt retained in the cheese was not proportional to the amount added to the curd. Increasing the amount of salt tended to decrease the moisture content of the cheese. The increased amounts of salt were associated with decreased formation of water-soluble, protein derivatives. The increased amounts of salt probably delayed the action of ripening agents, and decreased moisture content undoubtedly had a similar effect.

TABLE 21:10. EFFECT OF DIFFERENT AMOUNTS OF RENNET UPON PROTEIN CHANGES IN CHEESE RIPENING
(Van Slyke and Hart, 1903)

| *Age of cheese* | *Rennet extract added for 1000 pounds of milk* | *Moisture in cheese* | *Nitrogen expressed as percentage of nitrogen in cheese in form of:* | | | |
|---|---|---|---|---|---|---|
| | | | *Water soluble proteins derivatives* | *Caseoses and peptones* | *Amino acids* | *Ammonia* |
| *months* | *ounces* | % | % | % | % | % |
| 1 | 3 | 38.45 | 18.20 | 9.95 | 8.29 | .... |
| 1 | 6 | 38.56 | 24.90 | 15.30 | 9.63 | .... |
| 3 | 3 | 37.97 | 27.90 | 13.39 | 12.60 | 1.96 |
| 3 | 6 | 37.61 | 33.20 | 16.35 | 14.70 | 2.18 |
| 6 | 3 | 37.59 | 31.80 | 12.84 | 17.30 | 2.23 |
| 6 | 6 | 36.79 | 36.80 | 16.76 | 17.30 | 2.70 |
| 12 | 3 | 36.07 | 40.40 | 14.10 | 23.60 | 2.93 |
| 12 | 6 | 34.51 | 48.10 | 15.34 | 27.50 | 4.60 |

**Rennet extract.** The data in table 21:10 show the effects of adding the normal amount of rennet, 3 ounces for 1000 pounds of milk, and double that amount. There was a greater increase of water-soluble, protein derivatives in the cheese containing the larger amounts of rennet. Formation of caseoses and peptones was stimulated to a greater extent by the extra rennet than was the formation of amino acids and ammonia. This was especially true in the early months of curing. These results of Van

Slyke and Hart appear to be in harmony with the findings of Babcock, Russell and Vivian (1900), Riddet, McDowall and Valentine (1933) and Freeman and Dahle (1938).

**Pasteurization of milk.** The delay in the production of cheese flavor caused by pasteurizing milk for Cheddar cheese is well recognized. Lane and Hammer (1935) pointed out that the formation of water-soluble protein derivatives was more rapid and extensive in cheese made from raw milk than in cheese made from identical milk after pasteurization. Call and Price (1944) reported that the extent of protein breakdown decreased with increasing severity of heat treatments. It is interesting to note in this connection that the curdiness of cheese made from pasteurized milk disappears at essentially the same rate as that in raw-milk cheese of comparable quality and composition. This is a significant resemblance which may indicate that the essential agents causing body breakdown do not include the normal flora of raw milk.

## REFERENCES

Babcock, S. M., Russell, H. L. and Vivian, A. (1900). Wis. Agr. Expt. Sta., 17th Ann. Rept., pp. 102-122.

Babcock, S. M., Russell, H. L., Vivian, A. and Baer, U. S. (1902). Wis. Agr. Expt. Sta., 19th Ann. Rept., pp. 180-183.

Babel, F. J. and Hammer, B. W. (1945). J. Dairy Sci., *28,* 201.

Calbert, Harold E. and Price, Walter V. (1948). J. Dairy Sci., *31,* 713.

Call, A. O. and Price, W. V. (1944). J. Dairy Sci., *27,* 681.

Dahlberg, A. C. and Kosikowsky, F. V. (1947). J. Dairy Sci., *30,* 165.

Dahlberg, A. C. and Kosikowsky, F. V. (1948). J. Dairy Sci., *31,* 305.

Daniel, Louise, and Norris, L. C. (1944). Food Res., *9,* 312.

Davies, A. W. and Moore, Thomas (1939). Biochem. J., *33,* 1645.

Dorn, F. L. and Dahlberg, A. C. (1942). J. Dairy Sci., *25,* 31.

Freeman, T. R. and Dahle, C. D. (1938). Pa. Agr. Expt. Sta., Bul. 362.

Guerrant, N. B., Dutcher, R. A. and Dahle, C. D. (1938). J. Dairy Sci., *21,* 69.

Harper, W. J. and Swanson, A. M. (1948). J. Dairy Sci., *31,* 715.

Higuchi, Kiyoshi and Peterson, W. H. (1946). J. Dairy Sci., *29,* 789.

Higuchi, K., Price, W. V. and Peterson, W. H. (1946). J. Dairy Sci., *29,* 157

Hiscox, E. R. (1941). Chem. and Ind., *60,* No. 31:563.

Hiscox, E. R., Harrison, J. and Wolf, J. Z. (1941). J. Dairy Res., *12,* 155.

Irvine, O. R., Bryant, L. R., Sproule, W. H., Jackson, S. H., Crook, A., and Johnstone, W. M. (1945). Sci. Agr., *25,* 817.

Irvine, O. R., Bryant, L. R., Sproule, W. H., Jackson, S. H., Crook, A., and Johnstone, W. M. (1945a). Sci. Agr., *25,* 833.

Lane, C. B. and Hammer, B. W. (1935). Iowa Agr. Expt. Sta., Res. Bul. 183.

Lane, C. B. and Hammer, B. W. (1939). Iowa State College J. Sci., *13,* 149.

Lane, C. B. and Hammer, B. W. (1939a). J. Dairy Sci., *22,* 432.

Lane, C. B. and Hammer, B. W. (1941). Iowa Agr. Expt. Sta., Res. Bul. 291.

McCammon, R. B., Caulfield, W. J. and Kramer, N. M. (1933). J. Dairy Sci., *16*, 253.

McDowall, F. H. and Dolby, R. M. (1935). J. Dairy Res., *6*, 218.

McDowall, F. H. and Dolby, R. M. (1936). J. Dairy Res., *7*, 156.

McDowall, F. H. and McDowell, A. K. R. (1939). J. Dairy Res., *10*, 118.

Peterson, Merlin H., Johnson, Marvin J. and Price, Walter V. (1948). J. Dairy Sci., *31*, 39.

Peterson, Merlin H., Johnson, Marvin J. and Price, Walter V. (1948a). J. Dairy Sci., *31*, 55.

Riddet, W., McDowall, F. H. and Valentine, G. M. (1933). N. Z. Dept. Sci. and Ind. Res., Bul. 38.

Suzuki, S. K., Hastings, E. G. and Hart, E. B. (1910). J. Biol. Chem., *7*, 431.

Tuckey, S. L. (1941). Nat. Butter and Cheese J., *32*, No. 9:12.

Tuckey, S. L., Ruehe, H. A. and Clark, G. L. (1938). J. Dairy Sci., *21*, 777.

Van Slyke, L. L. and Bosworth, A. W. (1907). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 4.

Van Slyke, L. L. and Bosworth, A. W. (1913). J. Biol. Chem., *14*, 231.

Van Slyke, L. L. and Hart, E. B. (1902). N. Y. (Geneva) Agr. Expt. Sta., Bul. 215.

Van Slyke, L. L. and Hart, E. B. (1903). N. Y. (Geneva) Agr. Expt. Sta., Bul. 236.

Zahrndt, H. J., Lane, C. B. and Hammer, B. W. (1944). Iowa Agr. Expt. Sta., Res. Bul. 325.

## CHAPTER 22

# PACKAGING CHEDDAR CHEESE

Cheddar cheese is usually pressed into shapes and sizes which are well adapted for handling in transporting and warehousing operations; these shapes and sizes are not so convenient for retail sales. The large cylindrical shapes are covered with paraffin and cloth bandages which cannot be easily removed by the retail store operator; even the square loaves present some handling problems. Some of these problems are: the sampling of cheese by clerks and prospective customers, the drying of the cheese between sales, and the maintenance of strict cleanliness in handling the cheese. The sale of food in packages is so simple and clean that the cheese industry has sought for many years to package cheese for retail distribution.

Early attempts to merchandise cheese in units of more convenient size resulted in the manufacture of smaller styles of cheese. Daisies, Longhorns, Young Americans are common small styles; there are others. In more recent years new methods and materials for packaging cheese have been developed. It is our purpose to mention general requirements of packages, to describe some of the practical developments, and to call attention to significant advantages and disadvantages of these developments.

## GENERAL CONSIDERATIONS IN PACKAGING CHEDDAR CHEESE

Many methods of packaging natural cheese have been devised. Some of them have been patented. Some methods seem to fill certain needs better than others. No single method, as yet, seems to be ideal for all purposes, although some methods are excellent for some purposes.

Conditions of packaging and merchandising vary widely in terms of time required from packaging to selling, temperatures of holding, and the severity of shipping and handling conditions. These conditions will be discussed systematically under the headings: cheese requirements, conditions of packaging, and consumer requirements.

### CHEESE REQUIREMENTS

The cheese must be of uniformly high quality to please the consumer, to inspire confidence in quality, and to encourage repeat sales. Cheese of such quality is most dependable in curing and in keeping properties. Pasteurized-milk cheese is highly regarded for packaging purposes because it has a relatively low rate of gas development in curing, and because it satisfies the ideals of health regulatory officials who are intensely interested in the healthfulness of foods of all kinds.

The cheese in the package must be clean, desirable, and characteristic in appearance. Specks on the cheese, uneven or un natural color, and finger prints are avoidable defects in packaged cheese.

The packaged cheese should retain its natural flavor, consistency, and desired shape. The typical flavor and aroma should not be altered by the packaging material used, nor by the process of curing the cheese in the package. It should be possible to indicate on the label the flavor intensity of the cured cheese. Moisture content of packaged cheese must be regulated to provide the desired body in the final package. This moisture content must be maintained by the package. Drying losses may change the color and the appearance, as well as the net weight of the cheese in the package. Rind formation and dried surfaces are inexcusable in a good package.

Cheese in packages must be protected against the growth of yeasts and molds. Such organisms destroy flavor, cleanliness of appearance, and sales appeal.

Cheese tends to oil off when held at high temperatures. Packages reveal or even exaggerate such tendencies. The tight cling of a transparent wrapper may minimize the visible effects of oiling, but only opaque wrappers and cans conceal them. Packages of natural cheese must be clearly labeled to indicate desirable temperature conditions for holding and merchandising.

Natural cheese develops gas most rapidly in the early stages of curing; some is evolved even when the cheese is fully cured. The gas is chiefly carbon dioxide if the cheese is normal. Valve-vented cans permit the gas to escape so they can be used for packaging cheese. Vacuum packaging of cheese in cans or flexible wrappers tends to lessen the effects of gas development. Some packages, other than cans, provide inconspicuous openings for venting the gas. If the gas is retained in a sealed package or can, the consumer is apt to assume that the swelling of the package indicates spoiled cheese. Cheese that is held in a tight container develops what is known as a "smothered" flavor; vacuum packaging tends to minimize the defect; exposing the sliced cheese to the air is helpful in removing some of this flavor.

The package should protect the cheese from physical damage such as crushing and contamination. This protection should extend to the consumer who should expect to find in the packaged cheese keeping properties at least equal to those of freshly cut cheese.

## CONDITIONS OF PACKAGING

The type of package or method of packaging is influenced by the places of packaging and marketing. Cheese is packaged at the factory, warehouse, or at the point of retail sale. There are types of packages adapted to each of these places.

Requirements for packaging at the factory include:

1. A "keeping" package that will permit normal ripening, provide for escape of gas, and give adequate protection to the cheese during the long curing period;
2. Skilled labor available at the factory to handle the extra operations;
3. Space for curing, for storing supplies, and for wrapping cheese under sanitary conditions;
4. Equipment for cutting, wrapping, weighing, and packaging;
5. Sufficient capital to finance the storage of cheese and maintenance of adequate stocks of wrapping supplies;
6. A sales outlet.

The conditions for successful packaging of uncured cheese at a warehouse are identical to those required at the factory level. These conditions include a suitable package, labor, space, equipment, capital, and sales outlets. Warehouse operators who are more directly concerned with problems of merchandising may find it simpler to sell packaged cheese than factory operators who are usually involved in problems of procurement, quality control, and manufacture.

Cured cheese may be packaged at the warehouse of the distributor in a city market. The keeping type of package is used for distant markets; if the life of the package needs to be only a few days, then an inexpensive type of wrapper to protect the cheese from handling and drying is adequate. The necessary keeping quality in such a wrapper may be achieved by holding at 32° to 35°F. until the time of retail sale.

The retailer who packages cheese requires little of the packaging in keeping quality. Instead he emphasizes that the package must have the greatest possible display value, ease of handling, and adaptability for use of spare-time labor in the store. Packaging operations in the retail store require a small, well-lighted space, sanitary equipment, tables, cutting utensils, and suitable cleaning facilities for hands and equipment. Some of the most effective operations in packaging cheese are thus carried on practically under the observation of the housewife. The methods and technique of packaging become an advertisement for the product and a point of interest for consumers.

## CONSUMER REQUIREMENTS

Consumer requirements, the satisfaction of which determines the success of the packaging program, include several factors:

1. *Economy.* The package offering the most food per dollar in a unit of convenient size and price attracts the attention of discriminating buyers.
2. *Quality.* Cheese is sold only to people who like it. The quality must suit the consumer and it must be uniform. Lack of uniformity destroys the merchandising value of the labeled package. The consumer cannot taste packaged cheese before purchasing it; he must depend on the brand to indicate quality.
3. *Cleanliness.* A clean package creates interest. Packaged cheese must be above suspicion. The product must be completely protected from contamination.
4. *Convenience.* The most convenient package is easy to choose, buy, carry, store, open, and use.
5. *Visibility.* The appearance of the cheese through a transparent wrapper creates desire and helps in choosing. An opaque container or wrapper must depend upon label design to stimulate interest.
6. *Sales appeal.* The package should be attractive, novel, and have prestige in brand name. These qualities must be displayed in the store by proper location of display, attractive arrangement, and identification by posters or signs. Properly informed sales clerks stimulate sales.

7. *Identity.* The names and addresses of the manufacturer or distributor, or both, are shown on the label; other information on the package usually includes such items as age of cheese, flavor, and whether the cheese was made from pasteurized milk. These facts tend to educate the buyer, establish confidence in the product, and some of them may actually be required by law.

## METHODS OF PACKAGING

### Waxed Prints of Cheese

Some of the earliest attempts to merchandise cheese in convenient packages lead to the making of small styles of cheese. Miniature cheddars, weighing only one or two pounds, were typical of such packages. Farrington (1901) made small prints of cheese for direct sale to consumers.

In recent years hoops have been designed to make blocks of cheese which can be subdivided and cured in prints as small as one pound. Each print can be finished with a smooth, sound surface like any larger style. This is done by using cloth-wrapped dividers to keep the prints separate during pressing, and by so turning the prints that all surfaces touch the press cloth at some time during the pressing operations.

These small prints of cheese, which commonly weigh one, two, or five pounds, are removed from the hoops and dried carefully to form a light rind. They are dipped in wax or paraffin as soon as they are dry. Each print is dipped individually by hand to obtain the smoothest surface. First one end of the cheese is inserted in the hot wax and then, after an interval to permit the cooling and firming of the wax, the other end is dipped deeply enough in the hot wax to cover the print completely. The small sizes are frequently coated with more than one layer of wax to prevent excessive drying during the ripening period.

The prints of cheese are ripened at the usual curing temperatures. They may be held in boxes during this period to facilitate handling, to protect them, and to prevent excessive drying. When the cheese has reached the desired stage of curing, it is wiped off with clean cloths to remove superficial spots of mold. It can be rewaxed to give it a high gloss if the waxing is carefully done.

Two methods are used most commonly to identify these prints of cheese for sales purposes. Each print may be placed in a paraffined carton which contains the necessary identification of the product, brand name, manufacturer and his address, and any other necessary information or advertising. Such cartons of cheese are packed in corrugated cardboard boxes or square wooden boxes for shipment. The second method of identifying the waxed print is to cover it with a transparent wrapper on which is printed all the necessary information and identifying labels. Such prints are packed in wood or cardboard for shipment to distant markets. A third method of identification is occasionally used; it consists of sticking a printed label on the hot wax at the time of dipping. These types of packages are distributed widely by factory-to-consumer sales and by mail order sales. Some factory brands are well known in the wholesale trade.

There are four outstanding advantages of this type of packaged cheese: It is easy to make under factory conditions without much extra equipment. Well known and reliable methods are used; they have been proven by years of practice. The curing process is normal, if evaporation losses are minimized by careful waxing, boxing, and humidity control. The cheese is obviously "natural" cheese; this has a great appeal in certain markets.

The waxed prints of cheese have certain disadvantages: Extra labor is required in the factory for dressing, pressing, and waxing. There is a slight amount of rind under the wax that may be discarded by the consumer as waste. Drying losses in ripening are approximately double those of the same cheese in larger styles like cheddars. Each print at the time of sale must be individually inspected and cleaned, if necessary, to remove mold growth. Curd selected for this special treatment must be of high quality; inferior cheese will cause excessive losses.

## WAXED SLICES OR PRINTS OF CURED CHEESE

In recent years great improvements have been made in the flexibility of paraffin by blending it with microcrystalline wax. The resulting combination has been sold to the cheese industry under the general name of **flexible wax**. This product has been used for coating slices of cheese or prints of cured cheese. The coating is purposely made thick by using temperatures of dipping that are close to the congealing point of the wax. Such heavy layers of wax can be peeled from the surface of the cheese when it is cut for serving. The waxed cheese is then wrapped in printed transparent wrappers for merchandising. Sometimes the package is identified by a paper label applied while the wax is still hot.

This method of packaging has two outstanding advantages: It is simple to apply and low in cost. It is applied to the cured cheese so that the quality for merchandising is known at the time of packaging. The method has certain disadvantages: Off flavors from the wax or from changes on the surface of the cheese are sometimes developed under the wax. A large amount of partially edible trim remains after cutting the cheese into prints. Breaking of the wax coating permits mold to grow under the wax.

## Wrapped and Waxed Prints of Cheese

Fresh or cured cheese can be cut into prints, wrapped in heat-sealing foil, sealed, and then coated with flexible wax (Wis. Agr. Expt. Sta., 1940). The foil is 0.0007 inch in thickness and is tightly wrapped about the cheese to exclude air. The temperature of the wax at dipping is near the congealing point so that the foil-wrapped cheese is covered with a coating not less than one-sixteenth of an inch in thickness.

Gas developed during the curing of the cheese in the package escapes slowly enough to prevent swelling of the package under normal conditions. It is advisable, however, to minimize gas production by using high quality, pasteurized milk for making the cheese, by developing the proper amount of acid in the cheese, never too little, by delaying wrapping of the cheese for a few days after making, and by curing the cheese at 40°F. or less. Loose wrapping or faulty dipping will permit growth of mold in this package.

The advantages of the waxed-wrapped print of cheese are: the simplicity of making; elimination of surface taints; complete separation of cheese from wax; and all the protective attributes of the heavy wax coating. The principal disadvantages of the method are: the amount of hand labor required; the opaque wrapper which lacks sales appeal; and the necessity of handling care to prevent crushing.

## Canned Cheese

The canning of cheese in glass or metal containers is one of the oldest methods of packaging cheese. For many years farmers near cheese factories have packed, sealed, and cured fresh curd in fruit jars. Pernot (1901) sealed Cheddar cheese in cans to preserve its quality and advocated the treatment. Sherman (1927) reported the successful canning of cheese in vacuum; he used glass containers. Stevenson (1932) placed cheese in a sealed container, removed the air, and replaced it with nitrogen or carbon dioxide to prevent spoilage. Use of carbon dioxide and nitrogen for gas-packing cheese was studied by Golding, Reynolds and Prouty (1946).

Rogers (1932) pointed out that, when cheese is packed in a can so that air space is limited, mold develops very little or not at all. He provided a relief valve to permit the escape of gas produced by the ripening cheese. He stated that the increased cost of cheese in this package was largely offset by the decrease in handling costs and evaporation losses. Wilson (1935) successfully demonstrated in factory practice the canning procedure which Rogers had developed. Wilson (1940) described the packaging of sandwich slices of Cheddar and Swiss in valve-vented cans.

Reichart (1935) used the valve-vented cans for curing cheese at approximately 60 F. McCubbin and Reichart (1937) observed that the canned cheese cured at 40 F. was continuously superior in body and flavor to that cured at 70°F.

Doane (1940) commented on the retention of two distinctive flavors in cheese ripened in cans even when the venting valve was used. He referred to one flavor as "salty acid" or "metallic" and stated that it was permanent. The second, a putrid flavor and odor, he pointed out, tended to disappear on exposure to air. Doane believed that these flavors always developed in normal cheese, but they were intensified in canned cheese.

Golding (1941) proposed to minimize gas development in canned cheese by using selected, pasteurized milk for cheese making and by sealing the cheese under vacuum. His cheese was cured at low temperatures and held under cool conditions during retailing without producing enough gas to bulge the cans. Golding (1942, 1942a, 1944) found that temperatures much above 50°F. were not satisfactory; that delayed canning and slicing of cheese slightly reduced gas production; and that combining *Streptococcus lactis* and *Lactobacillus bulgaricus* in starter for cheese gave the least gas production for three months. He took vacuum-packed cheese, which had been aged for over a year in cool storage, and placed it at 70 F.; gas developed in the cans and the quality deteriorated so he recommended that aged cheese in cans should be held at 52 F. or less in order to maintain quality during merchandising.

Dorn and Dahlberg (1942) found that the carbon dioxide evolved during ripening of raw-milk Cheddar cheese varied from 0.13 to 0.20 per cent of the weight of the cheese; that evolved by pasteurized-milk Cheddar varied from 0.04 to 0.09 per cent. Dahlberg and Marquardt (1942) studied the possibility of curing Cheddar in ordinary tin cans without permitting the gas to develop excessive pressures. They maintained lower pressures by using pasteurized milk for the cheese, by sealing the cheese under 22 inches of vacuum, and by placing calcium or magnesium hydroxide in the cans to combine with the carbon dioxide produced. They preferred cheese cured under vacuum.

It is obvious that the canning of cheese merits the serious consideration of both manufacturers and merchandisers. Experimental work indicates the feasibility of canning the fresh curd and curing the cheese in the cans; the cured cheese can be canned and merchandised successfully. The aged cheese can be canned at any convenient point in the merchandising routine; the fresh cheese must be canned in or near the place of manufacture.

**Methods of canning.** The procedures for canning cheese in valved containers described by Wilson (1935) can be applied with suitable modifications to other types of containers. The modifications required are those suggested by the experiments of Sherman (1927), Golding (1941), and Dorn and Dahlberg (1942). Wilson's directions and recommendations are:

1. Supplies and equipment needed include: special hoops for forming the milled curd into suitable size and shape; cotton cloth wrappers and press cloths; cutting device to reduce loaves to prints; material like Cellophane or parchment paper for wrapping prints to be placed in cans; valve-vented cans; can-sealing machine; and shipping cartons.
2. Special hoops are filled with curd, balanced to correct weight, pressed, dressed, and repressed.
3. Pressing cloths are removed; loaves are cut into pieces of desired weight; pieces are wrapped, placed in cans and sealed; cans are packed in shipping cartons, and cartons are placed in curing storage.
4. Curing temperatures acceptable for normal cheese are used for canned cheese. Slightly higher temperatures

can be applied with less danger of spoilage or damage by mold and insect pests.

5. The cheese is examined periodically to detect development of defects or other faults during curing.
6. Cans of cured cheese are labeled, replaced in cartons, and moved into the usual trade channels.

**Precautions in canning.** Wilson (1935) suggested certain precautions to observe in canning cheese; some others, in addition to his, are included in the following:

1. Use selected milk and pasteurize it to maintain uniformly high quality.
2. Use only the best curd for canning; it should not contain over 37.5 per cent moisture. Curd which will not make cheese scoring 91 or better is unsuitable for canning.
3. Fast-working curds and cheese containing too much acid are particularly undesirable for aging in cans.
4. Weigh curd into hoops to minimize trimming losses.
5. Label cans to show grade and any other necessary information required by state and federal regulations.
6. Cure canned cheese carefully; avoid exposing it to temperatures as high as 70 °F.; place suitable warnings and instructions on the labels for the information of the retailer and consumer.

Wilson estimated, at cost levels prevailing in 1935, that cheese canned in 5-pound oblong cans or in 12-ounce round cans with venting valves would have to be sold at 2 and 6 cents more per pound, respectively, to net the same amount of money as the cheese would command if it were sold as Daisies.

There are several outstanding advantages of packaging cheese in cans: There is no shrinkage of weight after canning. The cans protect the product during shipment and merchandising from practically all abuse except exposure to high temperatures. Distribution is simplified by providing guaranteed quality, uniformity, and convenient units, and by eliminating costs of cutting, weighing, sampling, wrapping, and drying in stores. The canning operation can be partly mechanized. The consumer can hold the cans under refrigeration until they are needed.

Merchandising cheese in cans has certain disadvantages: Special machinery is essential for closing the cans. The quality of the cheese must be carefully controlled and protected during making, canning, curing, and distribution. Failures in quality after canning are expensive because the costs of canning must be regarded as additional losses. Markets must be developed for canned cheese. Higher costs of production tend to limit the market for the cheese. After the cans are opened, the keeping quality of the cheese is no better than that of any other natural cheese. The "smothered" flavor is particularly noticeable in canned cheese with the possible exception of that packaged and held under vacuum. The retailer is apt to treat canned natural cheese like a "preserved" product rather than as a product which is actually perishable.

## FLEXIBLE WRAPPERS FOR CURING AND MERCHANDISING CHEESE

Flexible wrappers of many types have been tried and some are being used commercially for curing and merchandising Cheddar cheese in packages. As more is learned about the requirements of successful wrappers and their use it is certain that more kinds will become available.

Flexible wrappers which have been widely used for commercial operations have the following properties in common: They are relatively impermeable to moisture vapor and oxygen. They are slightly permeable to carbon dioxide. They cling or stick to the cheese under the conditions recommended for applying them. They are usually transparent or translucent. They are applied when the cheese has reached its final form during or at the end of the pressing operation.

The methods of applying flexible wrappers to Cheddar cheese differ with the type of wrapper. Manufacturers of wrappers are prepared to give specific instructions, sometimes personal demonstrations of proper procedures. This field of development is changing so rapidly that no prospective operator should attempt to engage in commercial cheese packaging operations without the most recent information obtainable from the manufacturer of the wrapper he proposes to use.

The Menasha Products Company (1939) developed Parafilm (Abrams, et al., 1937) and Parakote for wrapping natural cheese. Parakote is the registered trade name for a semi-transparent cellulose wrapper, coated on the inner side with a wax-like compound to seal to the cheese. The following outline indicates the general procedures recommended for using Parakote to wrap 10-pound blocks of cheese; smaller or larger units are packaged in a similar manner:

1. Press 21.4 pounds of high quality curd in a stainless steel 20-pound Wilson-type, multiple hoop. Line the top and bottom of the hoop with brine-soaked press cloths and press for one to two hours. This forms a block approximately 3¼″ x 14″ x 11″.
2. Cut the block of cheese in half, lengthwise; insert a cloth-wrapped, metal divider between the halves; rewrap the two blocks, as one, in a brine-soaked cloth which covers all surfaces smoothly; replace the blocks in the hoop; and repress for at least 3 hours.
3. Take the two 10-pound blocks from the hoop and remove the press cloth.
4. Place each block on the coated side of a 21-inch square sheet of Parakote and wrap smoothly with moderate tension. The "Lap fold" illustrated in figure 22:1 is recommended for units weighing 2, 5, 10, 20, 40, and 80 pounds. Overwrap each block with the slip sheet that is packed between the Parakote wrappers to prevent the wrappers from sticking together.
5. Replace the wrapped blocks, with the divider between them, in the hoop and apply full pressure overnight. Pour water at 100° to 105°F. over the hoop to seal the wrapper to the cheese. Air is excluded before the seal is completed. A warm room may be better adapted than the warm water to accomplish the purposes of the final pressing operation.
6. Remove the packages from the hoop the next morning and place them in a wood, fiber, or corrugated container measuring 3½″ x 14″ x 11⅛″ (inside dimensions) and store them for curing.

The Goodyear Tire and Rubber Company developed a transparent wrapper known as Pliofilm. Jones (1941) described in detail the application of this product in curing and packaging cheese for merchandising. Pliofilm is a synthetic material, varied in composition to meet specific needs; cheese requires the practically odorless film. The following outline indicates the main steps, but not details, of general procedures for curing and packaging cheese by the method described in the report by Jones:

1. Press 21 pounds 7 ounces of curd of high quality in 20-pound hoops for 45 minutes. Adjust the weight of curd to give 20 pounds 5 ounces and wrap the block smoothly in a brine-soaked press cloth and press overnight.

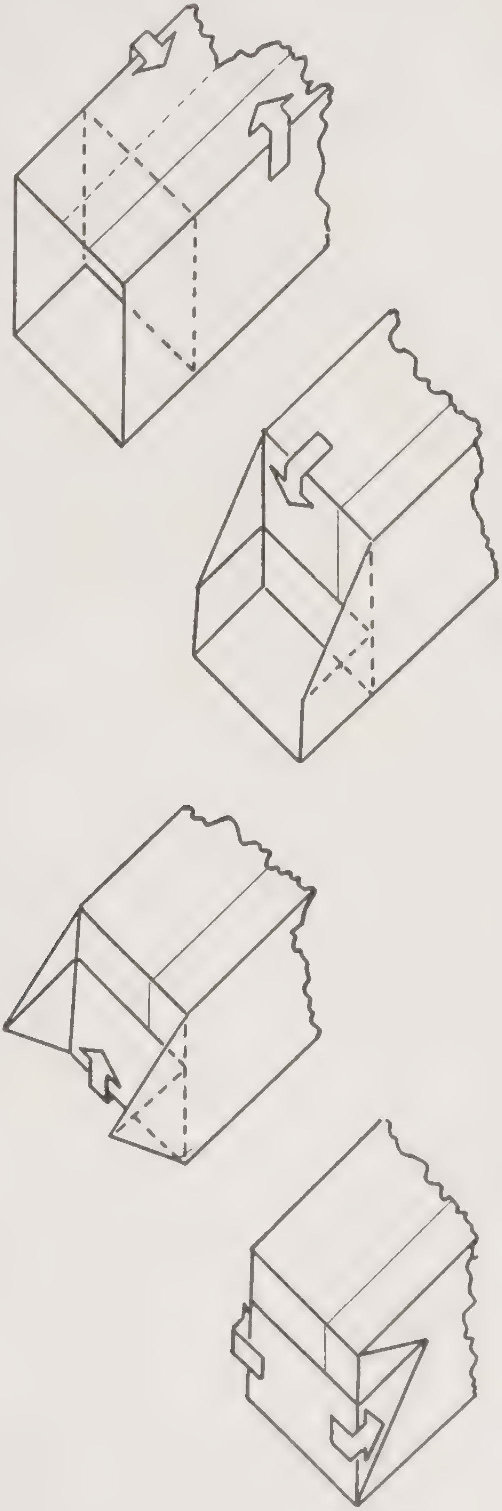


Figure 22:1. The lap fold is made by:

a) wrapping the loaf of cheese tightly with the lap on a long side of the loaf;

b) pressing the lapped edges downward over the end of the loaf and folding in the doubled edges;

c) lifting the bottom edge to overlap the upper part of the end closure;

d) and by turning the two ears back smoothly along the sides of the loaf.

2. Remove the press cloth and rewrap the block immediately in 40 GA NI Pliofilm before the surface of the cheese dries. Fasten the Pliofilm wrap with short pieces of Scotch Tape. Overwrap the Pliofilm-covered blocks with glassine paper.
3. Pack the blocks in special boxes 11⅛″ x 14$\frac{1}{16}$″ x 3⅝″. These boxes are made with slip-in covers so that when they are fastened they exert pressure on the cheese and tend to exclude air from the unsealed package. This procedure according to Jones (1944) is part of the "pressure pack" system for which patent applications have been made.
4. Hold wrapped and boxed cheese at 70°F. for four days. Cure at 40° to 50°F. for the desired period, usually 5 to 7 weeks. The cheese is said to cure faster in this type of package.

Jones (1944) further described the making of consumer units from these 20-pound blocks. This is now a common procedure when this wrapper is used:

1. Remove the unopened boxes of cheese from the curing room and hold them for 24 to 48 hours in a room at 75° to 80°F. Place them on skeleton shelves to allow free air circulation.
2. Remove the cheese from the box and strip off the glassine paper and Pliofilm wrappers.
3. Divide the 20-pound block with a wire printer into units of the desired size and adjust the weights of light pieces with thin slices. The adjustments should be of a minor nature.
4. Rewrap the small units immediately in 40 GA NI Pliofilm; "set" the creases by sliding the wrapped prints across the smooth table top after the end folds have been made. This wrapper is not sealed.
5. Apply an outer wrap of 80 gauge Pliofilm or a similar protective wrapper but do not entirely seal this outer wrap. Heat sealing must be done cautiously to prevent shrinking the 40 GA NI inner wrapper.
6. Handle the prints during the cutting and wrapping operations so that they can be assembled and repacked in the box in the same position relative to each other that they occupied before printing.
7. The box to hold the prints must be lined with die-cut

paper to provide a smooth surface around the prints. Pressure *must* be exerted on all surfaces of the prints as they are returned to the box; this is accomplished with a metal sleeve which is removed from around the prints after they have been properly positioned. The box maintains this pressure continuously.

8. Hold the pressure-packed prints for 6 to 12 hours at 65 to 70°F. then refrigerate them for not less than 24 hours to cool them thoroughly. The cheese should be held at temperatures below 50°F. at all times.

Visible mold growth probably has been the chief cause of deterioration of natural cheese in the flexible type wrapper. The Parakote wrapper tends to prevent mold growth by the sealing of the wrapper to the cheese. This is accomplished with the tissue-thin Pliofilm by its ability to cling to the surfaces of the cheese. This clinging effect is promoted by the moist surface of the cheese when it is wrapped, by the swelling of the cheese in the tight box before curing temperatures are applied, by warming the cured cheese before printing until part of the fat is in a liquid condition, and by repacking and maintaining the wrapped prints under pressure in the shipping boxes. Both wrappers exclude oxygen from the package and are effective only as long as they continue to do so. The normal development of carbon dioxide in the ripening of the cheese is responsible in part for the exclusion of oxygen because it maintains a slight positive pressure within the package.

There are several advantages in merchandising cheese in the flexible wrapper: Drying losses are minimized or eliminated. The packaging operations are suitable for carefully managed factories as well as for warehouses and large distributors. The wrappers can be used on cured cheese. The labor and other costs of making small prints can be avoided if the initial curing period produces an unsatisfactory product. The visibility of the cheese has great sales appeal. This package, like others, protects the cheese against contamination in handling and expedites store sales by identifying quality, uniformity, and weight.

The flexible wrapper has certain disadvantages: Rough or careless handling will break the bond or cling between the wrapper and the cheese. Quality control during making and curing must be above the average in order to maintain continuous production. Markets must be developed and merchandising personnel must be educated to handle this package properly. Higher costs of production tend to limit the market. The cheese must be carefully cured and promptly merchandised to avoid "smothered" flavor. Surface taints and flavors sometimes develop beneath the wrappers.

Deterioration of cheese from mold growth in flexible wrappers has been prevented by sealing the cheese in an atmosphere of carbon dioxide (Wis. Agr. Expt. Sta., 1940). More recently cheese has been packaged for commercial distribution in air-tight flexible wrappers from which air has been exhausted before the package was sealed (Hopkins, 1940; Berch, 1941). The success of such packages depends upon the use of cheese of such quality that excessive amounts of carbon dioxide do not accumulate in the sealed containers during the period of merchandising.

These wrapping materials and methods of application illustrate trends in methods for packaging natural cheese. Other methods should be mentioned to show the variety of possibilities in this field. Fassbender (1942) coats aged cheese with a mixture of wax and a rubber derivative to make a resilient, flexible casing. The cheese in its casing is snugly wrapped in an outer sheet of regenerated cellulose moistened with a water solution of glycerin and gum arabic. The sheet seals and shrinks in drying and presses the flexible wax casing against the cheese. Pape and Langwill (1942) described a wrapper for merchandising partially cured cheese. It consists of foil joined to Pliofilm with Vistanex. The cheese is sealed in this wrapper. When a pressure of carbon dioxide develops around the cheese it distends the wrapper and then slowly escapes through the seal; the package, however, remains substantially hermetically sealed. Jones (1947) indicates that large styles of Cheddar can be cured in suitable films by excluding air from the wrapped cheese. This he accomplishes by placing the wrapped cheese in a tightly fitting container.

## Fast-freezing Packages of Cheddar Cheese

Price (1935) described the use of freezing temperatures for preserving, packaging, and merchandising Cheddar cheese in small units. By this method Cheddar cheese, which had been cured to its ideal flavor, was cut into prints weighing 8 to 16 ounces. The thickness of the prints was no more than one inch in order to hasten freezing. The prints were wrapped in heat sealing aluminum foil and then were completely frozen in an air blast in 30 minutes or less. Temperatures of −10 F. were used for this purpose. The cheese was then packed in cartons and held at 0 F. Eight-ounce packages of cheese defrosted in approximately 45 minutes at room temperatures.

There are four advantages of this packaging procedure that are characteristic of it: The cheese is packaged at the peak of its quality. The treatment maintains the quality unchanged. The cheese does not oil off, overcure, crush out of shape, nor develop mold beneath the wrapper. It becomes one of the family frozen foods offered in the frozen foods cabinet of the retail store.

The fast-freezing procedure has certain disadvantages: The color of the cheese is mottled while the cheese is in the frozen condition; it is normal again when it is defrosted. Frozen transportation for long distances is expensive unless it can be accomplished in carload lots or with other similarly frozen foods. Sales appeal must be created by the wrapper rather than by the sight of the cheese itself. Sales are limited for practical purposes to retail outlets with facilities for handling frozen foods.

## PACKAGING CHEESE IN STORES

The cutting and wrapping of cheese in retail stores is a rapidly growing practice. The cheese is received at the store in its common form. It is warmed to room temperature before packaging if it is a hard cheese like Cheddar. Bandages are stripped off and the rind is brushed or scraped to remove bits of paraffin or brand marks. The cheese is then sliced with a wire cutter or knife into various sizes convenient to the prospective customer. Rind is not removed from the slices. Each slice is weighed, labeled with name and weight and usually price, and wrapped in a moisture-proof, heat-sealing transparent wrapping material like 300 M.S.T. Cellophane or Sylvania P.M.S. 300. The wrapper is pulled tightly over each cut of cheese and then sealed with a heat-sealing iron. These operations are commonly completed in the view of the passing customers.

There are several advantages to this system of packaging: The cost of the cheese delivered at the store is that of bulk cheese. Packaging is a "spare time" operation in the store. The cutting and wrapping operations attract favorable attention to the natural cheese. The wrapping offers the utmost in visibility and in choice of size and shape of package, but it prevents sampling and contamination. All types of natural cheese can be given the same treatment to build up a family of products to attract attention and encourage sales.

This system has certain disadvantages: The packages must be made shortly before they are sold because mold growth on Cheddar cheese can be expected under a tight wrapper in 3 days at 60 F. The attractiveness of the packaging operations depend on proper sanitary facilities, trained personnel, and adequate cutting and packaging equipment. Weighing must be carefully done on each piece of cheese to avoid errors in weights and prices of individual cuts. Store management must provide labor. The quality of the cheese purchased on the open market for packaging must be carefully supervised by the store management which must assume responsibility for pleasing the consumer. The identity of the cheese manufacturer is usually lost in this merchandising routine.

## SPECIAL MODIFICATIONS

**Club, Cold-pack, or Comminuted Cheese.** This type of product is prepared by grinding and mixing together, without heating, one or more lots of ripened cheese of the same or different varieties. Soft, unripened cheese, like Cream, Cottage, and Neufchatel, are not used. Water, salt, and color may be added. The cheese should be made from pasteurized milk or should be aged in accordance with legal requirements for distribution in certain restricted markets. Fat and moisture requirements are determined by the legal limits for the cheese used in the blend.

This type of cheese is distinguished for its high cheese flavor. Aged Cheddar is the variety most commonly used. Grinding and mixing change the body of the original cheese; it is very difficult to eliminate entirely all traces of mealiness resulting from these operations. When this cheese mixture is made at home, and not for sale, it is mixed with butter to give a smoother consistency and pleasing richness. The addition of fat to a mixture for commercial use makes it subject to a federal law which restricts the manufacture and sale of "filled" cheese.

These cheese mixtures are commonly packaged in opaque glass or porcelain containers with tight fitting closures; they may be wrapped in foil for quick sale purposes. New types of rigid, cardboard cartons with moisture-proof and grease-proof liners are being used more and more for this cheese. Another common package is made by extruding the cheese into flexible wrappers shaped like sausage casings. Cheese in such packages may be smoked or flavored with a smoke precipitate or condensate. All packages used for these ground cheese mixtures are intended to exclude oxygen from the cheese. This is accomplished by compression in filling containers or wrappers; by using tightly fitting wrappers, seals and covers; and by packaging under vacuum.

These types of packaged, natural cheese have certain advantages and disadvantages. They are more uniform because they are made by selecting and blending the cheese. Cheese flavor tends to increase when the mixtures are held at curing temperatures. The operation provides a market for edible portions of natural cheese left over from printing operations. On the other hand, the cheese tends to mold easily; carbon dioxide develops more rapidly in the ground cheese and causes openings in the cheese; the body is unlike natural cheese in slicing properties and has a tendency toward mealiness.

## REFERENCES

Abrams, Allen, Wagner, Charley, and Davis, Benjamin F. (1937). (to Marathon Paper Mills Co.) U. S. Patent 2,077,300 (April 13, 1937).

Berch, S. H. (1941). U. S. Patent 2,241,943 (May 13, 1941).

Dahlberg, A. C. and Marquardt, J. C. (1942). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 265.

Doane, C. F. (1940). Nat. Butter and Cheese J., *31,* No. 7:12.

Dorn, F. L. and Dahlberg, A. C. (1942). J. Dairy Sci., *25,* 727.

Farrington, E. H. (1901). Wis. Agr. Expt. Sta., 18th Ann. Rept., 132-135.

Fassbender, Hubert (1942). (to Milprint, Inc.) U. S. Patent 2,302,200 (Nov. 17, 1942).

Federal Security Agency, Food and Drug Administration (1947). Federal Register, *12,* 37:1192.

Golding, N. S. (1941). Proc. 27th Ann. Meeting, Western Div., Amer. Dairy Sci. Asso., 79-89.

Golding, N. S. (1942). Nat. Butter and Cheese J., *33,* No. 7:10.

Golding, N. S. (1942a). Wash. Agr. Expt. Sta., 52nd Ann. Rept., Bul. 425.

Golding, N. S. (1944). J. Dairy Sci., *27,* 679.

Golding, N. S., Reynolds, J. N. and Prouty, C. C. (1946). J. Dairy Sci., *29,* 495.

Hopkins, A. G. (1940). (to S. H. Berch) U. S. Patent 2,187,688 (Jan. 16, 1940).

Jones, L. H. (1944). How to cure and package natural Cheddar cheese in Pliofilm. Akron, Ohio. Goodyear Tire & Rubber Co.

Jones, L. H. (1947). (to Wingfoot Corporation) U. S. Patent 2,424,693 (July 29, 1947).

McCubbin, W. G. and Reichart, E. L. (1937). J. Dairy Sci., *20,* 466.

Menasha Products Company (1939). A manual of instruction for packaging natural cheese in Parafilm. Menasha, Wis., Menasha Products Co. (Div. of Marathon Paper Mills Co.).

Pape, Clifford B. and Langwill, James P. (1942). (to Reynolds Metals Co.) U. S. Patent 2,304,591 (Dec. 8, 1942).

Pernot, E. F. (1904). Oregon Agr. Expt. Sta., Bul. 78.

Price, Walter V. (1935). Wis. Agr. Expt. Sta., Res. Bul. 130.
Reichart, E. L. (1935). J. Dairy Sci., *18*, 477.
Reichart, E. L. and Downs, P. A. (1941). J. Dairy Sci., *24*, 19.
Rogers, L. A. (1932). J. Dairy Sci., *15*, 185.
Sherman, J. M. (1927). Glass Container, *6*, 5:18.
Stevenson, Albert F. (1932). (to Borden Company of N. Y.) U. S. Patent 1,868,547 (July 26, 1932).
Wilson, H. L. (1935). U. S. Dept. Agr., Circ. 352.
Wilson, H. L. (1940). U. S. Dept. Agr., Circ. 386.
Wisconsin Agr. Expt. Sta. (1940). Wis. Agr. Expt. Sta., 57th Ann. Rept., Bul. 450.

# CHAPTER 23

# PROCESS CHEESE

Process cheese is the food made from several lots of cheese that are comminuted or ground and mixed together by stirring and heating. Water, seasoning, color, and emulsifying salts may be added. Flavoring materials like pimentos and spices are sometimes used, or the cheese may be smoked or flavored with smoke condensate or precipitated smoke for additional character. Cheddar cheese is the variety most commonly processed in the United States. Process cheese is also made with Swiss, Limburger, Brick and similar varieties. The finished product usually contains somewhat more moisture than the original cheese from which it was made.

When cheese is blended with legally limited amounts of dairy products such as cream, milk, skim milk, or whey or their concentrates, and certain other optional ingredients, the mixture is known as a cheese food. Cheese foods usually contain more moisture and less fat than process cheese.

Cheese spreads are another modification of process cheese. They are made with cheese as a base but with the addition of optional ingredients, similar to those used in cheese foods, for desired flavor and body properties. Cheese spreads contain more moisture and usually less fat than cheese foods.

Process cheese has certain characteristics which make it popular with both the retailer, and the consumer. The former receives a unit which is usually attractively packaged, easily displayed, and subject to few merchandising losses, such as spoilage, or shrinkage in weight. The consumer finds in this packaged product uniform flavor, ease of purchase, no waste, and excellent keeping properties as long as the package remains unopened. Consumer taste tests by Hobson and Schaars (1935) indicated that more than half of the individuals tested preferred the flavor and body characteristics of this product.

## PROCESS CHEESE STANDARDS

Legal definitions of process cheese and similar products are being formulated and changed rather frequently to keep pace with new developments in materials, techniques, and consumer demands. Proposed federal regulations have been published by the Federal Security Agency (1947). These proposals, which are subject to modification in whole or in part, indicate trends in definitions.

The proposed definitions accept the idea that the process cheese may consist of one or more lots of cheese of the same or different varieties. The use of Cream or Neufchatel cheese however is not accepted for making "Pasteurized process cheese." The definitions indicate that the cheese will be comminuted, mixed together, and heated to form a homogeneous mixture. Water, salt, and harmless coloring material are accepted as optional ingredients.

The proposed definitions name several emulsifying agents which may be used alone or in mixtures; these include: disodium or dipotassium phosphates; sodium metaphosphate; sodium or potassium citrate; sodium tartrate; Rochelle salts, trisodium phosphate; sodium pyrophosphate, acid; and tetrasodium pyrophosphate. Three per cent of the total weight of the finished process cheese is the limit of the amount of these emulsifying agents.

The definitions proposed indicate the possibility of the necessity of acidity control by the addition of harmless acids. The list of acids which may be permitted include: lactic, citric, acetic, and phosphoric. These may be used alone or together, but the pH of the cheese should not be less than 5.3.

Sweet cream is acceptable as an optional ingredient providing the fat it contributes does not exceed 5% of the weight of the finished cheese.

The proposals indicate that the temperature of heating and the duration of the holding period will eventually be specified, and that the resulting product must have a practically negative phosphatase test when examined by the method of Sanders and Sager (1946).

The proposals suggest that the moisture content of process cheese may exceed by not more than one per cent the maximum permitted in the natural variety while the fat content may not be less than that of the natural cheese. Reasonable provisions are offered for limiting the moisture and fat contents when two or more varieties of cheese are used.

The proposed definitions indicate that specific labeling requirements will appear in the final definitions and that they can be expected to cover such items as naming of variety or varieties used; addition of smoke or smoke "flavor," optional ingredients, spices, flavoring materials; and the arrangement of the wording of the informative material.

### PATENTS

Certain patents were granted during the development of process cheese. To James L. Kraft (1916) was granted the first of several patents which marked the beginning of the commercial manufacture of process cheese in the United States. These and other patents described the essential steps in the making of process cheese. These steps included the manufacturing operations of blending, heating to various temperatures, stirring, sterilizing, and packaging. Other patents included the use of sodium phosphate, and sodium citrate. The variety of cheese such as Cheddar, Swiss and Camembert and combinations of them were specified in some of the patents. These fundamental patents, which largely controlled the production of process cheese had all expired by 1939. Certain patents still in effect cover the use of some machines, emulsifiers, and processes. Sommer and Templeton (1939) assembled a comprehensive list of approximately 100 patents pertaining to the various phases of the industry. These patents indicate the wide and continuing interest in the processes, emulsifiers, machines, packages, wrappers, and products produced.

## MANUFACTURE OF PROCESS CHEESE

### PROCUREMENT OF CHEESE

Cheese is selected and cured, some of it for several months, before it is used for processing. Manufacturers usually prefer to control the curing of their cheese so that the amounts and quality will satisfy their needs. Processing plants are frequently located in areas of cheese production so that fresh cheese can be easily obtained directly from the factories. Other operators prefer to manufacture the process cheese in areas near centers of consumption. Such operators tend to rely less on shipments directly from factories and more upon purchases made in the cheese markets of the country or through assemblers of cheese. Considerable foresight must be exercised in either method of procurement in order to provide each day the necessary amounts of current make and aged cheese to produce a blend of uniform quality. If, for example, the average age of the cheese in the blend is 90 days, then the process cheese plant operator must have in storage, or under contract, or otherwise available, approximately 90,000 pounds of cheese for every 1000 pounds of process cheese he intends to make on any given day.

## ANALYSIS AND GRADING

The operator who receives cheese directly from the factories performs the functions of the usual assembler of cheese. He samples the cheese for analyses for fat, moisture, and extraneous matter, and occasionally pH and salt content. This record stays with the cheese until it is ready for use. He grades the cheese to determine the market value and then sorts it according to its characteristics. Some lots are set aside for curing; others are marked for short holding or immediate use. Among the characteristics considered by the grader are flavor, body, texture, and finish. Those lots of cheese with minimum defects are marked for storage; those with minor defects may be used for short holding periods or may be used to provide fresh cheese in the blend. Each lot of fresh cheese is stamped, or otherwise marked to identify it, weighed, paraffined, and replaced in the boxes in which it was received from the factory.

## CURING CHEESE FOR PROCESSING

A small portion of fresh cheese can be used in making process cheese. Such cheese is moved immediately to the blending room or held in cool storage until it is actually needed.

**Temperatures of curing.** Two types of curing storage are commonly used. Storage at 35° to 45° F. is used for slow curing and mild flavor development; at the higher temperature flavor develops slightly faster than at the minimum temperature; body changes throughout the range are quite similar. Warm storage is used for holding cheese in which flavor and body breakdown are developed rapidly; temperatures range between 55° to 60° F. with relative humidities approximating 85%. Flavors and body changes in high-temperature curing are not like those obtained at low temperatures. The cheese may or may not be paraffined before it is placed in warm storage. If it is not paraffined, mold growth is heavy; if it is paraffined, fat tends to seep through the surface layers.

**Duration of storage.** Holding periods at the low temperatures vary from two or three months to a year or more. Treatments at the higher temperatures are rarely longer than 12 weeks nor shorter than 4 weeks. The increasing use of cheese made from pasteurized milk may be responsible in part for the use of shorter curing at higher temperatures. Costs of curing for long periods at low temperatures encourage the use of higher temperatures. Problems of controlling cheese quality, moisture losses and insect pests tend to discourage more general use of high-temperature curing.

## BLENDING

**Blending** is the operation of bringing together in a blend or batch, cheese from two or more vat lots. Blending produces desired characteristics during making and largely determines the uniformity of composition and quality of the finished process cheese. It is an important operation which requires judgment, experience, and technical skill.

**Selection of cheese for blend.** The selection of the cheese for the blend is determined chiefly by age, acidity, flavor, texture, body, and composition of the lots of cheese available. Some successful operators make their selections entirely on the basis of flavor, body and texture. The proper choice of the cheese must establish uniformly desirable flavor, body, slicing properties, and composition. These are attained by the mixing of many lots of cheese. While it is possible to use only one or two vat lots of cheese, it is highly desirable in commercial practice to use 20 to 30 vat lots. Such combinations frequently represent as many different factories as there are lots of cheese in the blend.

Usually the cheese available for processing can be classified into a few groups which have characteristic reactions in the processing operation. Sommer and Templeton (1939) suggested such classes in pointing out the desirability of using about 75% of cheese up to 3 months old with about 25% well-ripened cheese 6 to 12 months old. They stated that relatively young cheese produced smooth texture, firm body and good slicing properties; older cheese tended toward higher flavors, grainy texture, weak body, and poor slicing properties; high-acid cheese tended to produce grainy texture.

Barker (1939) described a good blend as consisting of four or five classes divided approximately as follows: 15% acid cheese, 15% current cheese, 15 to 50% of short-held cheese (2 to 3 months old) "on the acid side" but not acid, and 20 to 25% of short-held cheese, sweet and open. Storage cheese, six months old, he stated, could replace the short-held cheese in whole or in part.

Such classifications of cheese are variable and merely suggest approximate amounts to be selected from each group. Quality and defects of the cheese are carefully considered by the experienced blender in determining the amounts of various lots which can be used.

**Age of cheese for blend.** Cheese of different ages have different effects upon process cheese. Templeton and Sommer (1930) stated that very young cheese could not be processed without loss of fat but that after 8 days this tendency disappeared. Old cheese showed the same defect but emulsifier corrected it. These same authors (1932) indicated that the resistance to crushing decreased as the age of the cheese in the blend increased. Davel and Retief (1928) indicated the existence of this relationship by showing that aged cheese produced a soft, spreading type of body. Palmer and Sly (1943) stated that old cheese frequently gave loose, grainy, and oiled-off process cheese while fresh cheese produced a stable emulsion.

Templeton and Sommer (1930) advised that the average age of the cheese in the blend should be 4 to 7 months; such a blend they indicated, might consist of 2 to 3 parts of two months old cheese combined with 1 part of aged cheese. Barker (1939) advised blends of cheese averaging from 1.4 to 4.6 months of age. Use of cheese cured at high temperatures tends to reduce the average age of cheese in the blend.

**Acidity.** Davel and Retief (1928) found that the titratable acidity of a water solution of cheese was related to the properties of the finished process cheese. They recommended that the acidity should be held between 0.8% and 1.9%, calculated as lactic acid. These titration values reflected alkali-combining capacities of the water-soluble proteins as well as true acidity in terms of hydrogen ion concentration. At the lower levels of acidity the cheese was of the loaf, or slicing type; at the higher levels it tended to be of the spreading, soft type. They advocated the neutralizing of the cheese with ammonium hydroxide or acidification with lactic acid in order to attain the desired levels of acid.

Templeton and Sommer (1932) modified the body of process cheese by the addition of alkali and acid. They stated that results varied with cheese of different ages and lots. Maximum body was generally attained in the pH range of about 5.1 to 5.6.

Barker (1947) described "cheese on the acid side" as that which had 0.9% acid in the vat drippings before salting; and "cheese on the sweet side" as that made with 0.6% acid in the vat drippings. Barker (1939, 1941, 1941a, 1946, 1947) observed that acid cheese should be used cautiously in amounts not exceeding about 12 to 15%; that 45 to 50% of the batch should be "cheese on the acid side"; and that 20 to 25% should be "cheese on the sweet side."

**Flavor.** The intensity of cheese flavor in the blend is determined by the amount and intensity of flavor in the cheese selected. Some of the fine volatile flavors of well-aged cheese are lost in the processing operation. It is also a fact that some defective flavors are likewise lost in whole or in part. Fermented and fruity flavors may be dissipated. Non-volatile flavors such as bitter, salty, and acid must be blended carefully so that the intensity of the flavor is reduced below the objectionable level. Feedy and unclean flavors may be used cautiously. Weed flavors, like leeks, are dangerous when used in any amounts. Babel and Hammer (1945) found that when aged cheese, showing varying degrees of rancidity, was used at the rate of 25% of the blend, the flavor of the finished product was not rancid. Actually the process cheese made in this way was considered to have more cheese flavor than process cheese containing the same amount of identical aged, but non-rancid cheese.

**Texture.** Defects in openness of cheese are only significant to the blender when they indicate inferior quality or the presence of undesirable, spore-forming, gas-producing bacteria. Gassy cheese should be used sparingly; Barker (1947) suggested a limit of 2%. Spore-forming organisms survive the heat treatment of processing and some may cause gas development in the finished cheese if conditions for their growth are favorable. Chief among such conditions should be mentioned: heavy contamination, high temperatures, low salt concentrations, and pH levels above 5.3 to 5.6. Albus and Ayers (1928) showed that these organisms caused gassy fermentations of process cheese containing pimentos. Pimentos provided a fermentable sugar. When this sugar was eliminated by washing the pimentos, the defect was prevented.

Albus (1928) and Hanson, Spicer, and Price (1938) have described cheese made defective by the action of similar organisms.

**Body.** The desirable characteristics in a natural cheese are those which commend it for processing; they include smoothness, waxiness, firmness without toughness. Some defects in body of cheese to be processed are permissible when properly combined in the blend. Excessive hardness of dry cheese is not a serious fault; it can be corrected by the incorporation of moisture. Dry cheese commands a premium in price for processing purposes. Cheese that shows curdiness after 40 days of curing is undesirable. Shortness of body, indicative of acid cheese, is permissible when such cheese is used in limited amounts. Barker (1947) warned against the use of large amounts of tough, fresh cheese, and crumbly, acid cheese.

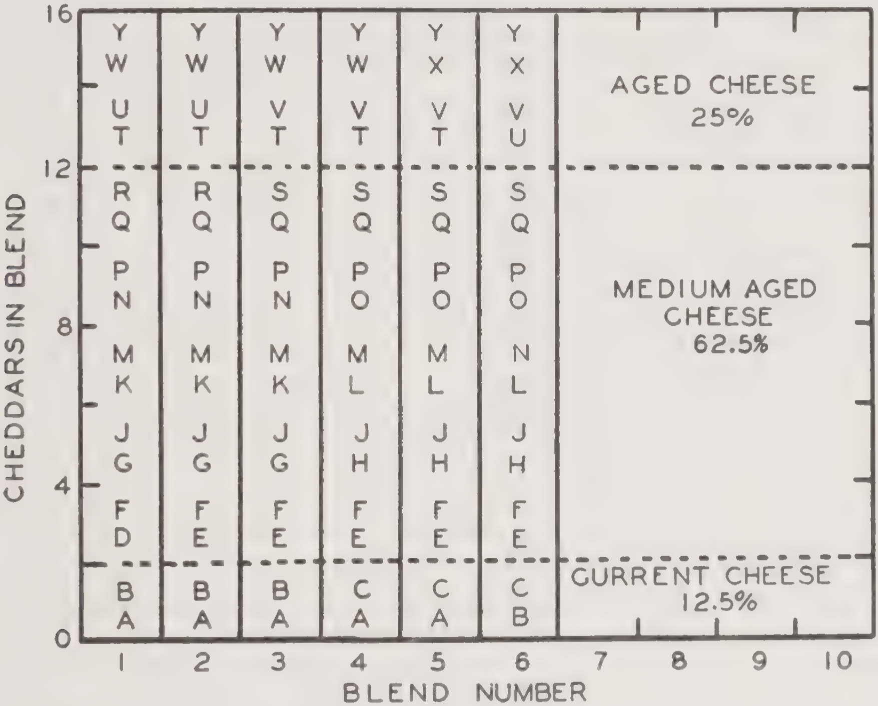
**Composition.** The composition of cheese selected for processing is important. Fat in the dry matter and the moisture of finished cheese must conform to legal standards. The most efficient use of fat is attained by combining vat lots of cheese with high and low percentages of fat. Standardization of milk for cheese frequently produces cheese with less fat in the dry matter than is desired for making process cheese. The use of emulsifying salts adds dry matter not fat, decreases the percentage of fat in the dry matter and creates a problem for the blender. A minimum safe amount of fat in the dry matter of the blend is usually regarded as 52 to 52.5%. This permits the addition of normal amounts of emulsifier and salt without decreasing the proportion of fat to less than 50% of the dry matter of the process cheese. Paying producers for making cheese for processing with more than the legal minimum fat content is entirely practical and may become necessary if standardization of milk for cheese is generally practiced (Price, 1946, and Erekson, 1946).

Moisture content of the blend may be controlled by the selection of cheese and by the addition of water during processing. When the cookers heat the cheese with direct steam the cheese selected must be of such moisture content that the water of condensation incorporated during the heating process does not produce an illegal product. Some processing kettles are so made that the cheese can be heated with either direct or indirect steam or both; this permits more control of moisture in the cheese.

**Arrangement and distribution.** After the vat lots of cheese to be processed have been classified, they are arranged to bring the proper amount of each to the grinder. Each vat lot of cheese is sampled again for fat and moisture analyses. The analyses of current cheese are not repeated.

During storage vat lots of cheese are kept together. When it is ready to use for processing the cheese is moved from the curing storage to the blending room. As it is brought into this room the cheese in the vat lots are distributed in new piles to form the blend containing the desired proportion of each class of cheese.

The distribution of the cheese to form the blend can be accomplished in several ways. One method is diagramed in figure 23:1. This diagram illustrates how floor space can be divided into areas to receive the cheese for each blend. As the vat lot to be processed, like vat A in figure 23:1, is removed from storage and brought to the blending room, each cheddar is placed in a different blend area. When that lot is exhausted, the next lot in the same classification is similarly distributed and so on, as were lots B and C in the diagram. In this manner the cheddars required in each of the three classifications, current,



CHEDDARS IN BLEND
0
4
8
12
16
Y Y Y Y Y Y
W W W W X X
U U V V V V
T T T T T U
R R S S S S
Q Q Q Q Q Q
P P P P P P
N N N O O O
M M M M M N
K K K L L L
J J J J J J
G G G H H H
F F F F F F
D E E E E E
B B B C C C
A A A A A B
AGED CHEESE 25%
MEDIUM AGED CHEESE 62.5%
CURRENT CHEESE 12.5%
1 2 3 4 5 6 7 8 9 10
BLEND NUMBER

Figure 23:1. This diagram illustrates a possible distribution of 23 vat lots of cheddars in making 6 blends of uniform quality. Letters are used to designate the different vat lots.

medium aged, and aged, are distributed so that no more than one cheddar of any vat lot appears in a single blend. The diagram has been limited in size to obtain clarity in the printed reproduction, so that it shows only 16 cheddars in each blend; quite commonly blends of twice this size are set up in processing plants. A record is kept with the blend to show the vat lots, weights and compositions of the cheese.

**Size of blend.** Blends containing approximately 30 cheddars are commonly used in commercial operations on the large scale. Such blends contain a total weight of approximately 2200 pounds, enough for four batches. The term **batch** is used here to designate the quantity of cheese processed at one time in a cooker. The larger cookers hold batches weighing 500 to 600 pounds. The 30-cheddar blend is conveniently divided by quartering the cheddars and putting one quarter into each of four batches. This system therefore extends over four batches the uniformity of composition of blends attained by the distribution illustrated in figure 23:1.

## CLEANING OPERATIONS

**Tempering.** Cheese is held in the blending room until it approaches a temperature of 60° to 70°F.; this may require 48 hours or longer. McDowall (1931) reported that when cheddars were removed from storage to a warmer room the temperature of the cheese became uniform in about 72 hours. Warming the cheese in the blending room softens it and facilitates the cleaning, cutting, and grinding operations; it has the added advantage of reducing the amount of heat required to bring the cheese to its final cooking temperature.

**Time.** The cheese is cleaned shortly before it is actually required for processing. The cheddars in one blend are moved to the cleaning area, taken out of the boxes, and placed on the cleaning tables, racks, or conveyors. The boxes are sorted for reuse or destruction.

**Method.** The first step in cleaning is the removal of paraffin and bandage. The paraffin is largely stripped from the cheese with the bandage. That which adheres tightly is scraped off; loose flakes are removed with a stiff brush. The debris is dropped into suitable containers beneath the cleaning area. This debris has some salvage value as a source of rags and paraffin or it may be burned.

This rough cleaning removes most of the soiled areas on the surface of the cheese. The cheddars are then moved to the next area, preferably another room, where all inedible portions of the cheese are scraped off or cut away. Short bladed knives and deck or box scrapers of various convenient designs are commonly used. Cheese scrapings fall through openings or grates in the cleaning tables or conveyors and are collected for salvage as waste fat and protein for stock feed.

**Trimming losses.** The amount of rind removed from a normal, undamaged cheese is determined by the flavor and consistency of the rind itself. The surface areas of cheese in storage absorb odors from boxes and storage rooms; the area affected must be removed in cleaning. A critical operator assumes that any portion of the surface that is not suitable for consumption in its natural state is undesirable for processing. Damaged rinds, cracked surfaces containing mold growth, moldy areas surrounding trier holes, spots damaged by box nails, and the like, are entirely removed from the cheese in this cleaning operation. Large styles of cheese tend to endure storage with smaller proportions of rind losses than smaller styles. Cheddars, are commonly preferred for processing for that reason. Weight lost in cleaning a cheddar may range from a few ounces in current cheese to several pounds in an old cheese which may have been damaged by excessive mold growth or other form of rind injury. It is being minimized by the use of flexible wrappers which cling to the cheddar or block and prevent drying and mold growth.

Brickner (1912) called attention to the desirability of using the rind of Swiss cheese in processing that variety. He suggested that the outer rind should be thoroughly cleaned with a wire wheel brush to remove all surface dirt, ink marks and damaged spots. He stated that the remainder of the rind, representing 15% of the cheese and containing relatively large amounts of fat and little moisture could be ground to powder fineness in a special hammer mill and used in amounts equal to one-third of the batch.

## GRINDING

**Quartering.** The cheese moves from the cleaning area to the cutter which divides each cheddar into quarters. This cutter is usually power driven; it forces the cheese against two taut steel wires crossed at right angles. This cutting in small scale operations is performed by hand by pulling a slack wire through the cheese to divide it first into halves and then into quarters. Each quarter is placed in a separate carrier to be conveyed to the grinder when all the cheese in the blend have been similarly divided and distributed.

**Grinders.** The grinding of large batches is accomplished by machines which first shred the cheese into small particles and then force it with a rotating beater device through a heavy metal perforated screen. These machines have capacities ranging upward to 15,000 pounds per hour, depending in part on the size of particles desired. They are operated by motors of 50 to 100 horse power. The feed hopper of this type of machine is large enough to accommodate the quarters of the cheddars. The comminuting of smaller batches is accomplished by the common type of meat grinder. The feed hoppers of such machines are relatively small so that the quarters of the cheddars must be subdivided into six or seven strips before grinding.

**Moving cheese to cookers.** The ground cheese is usually dropped directly into the cooker or cheese processing kettle. This is accomplished by locating the grinder on the floor above the cooker and connecting it to the cooker by a duct of wide diameter to permit the cheese to flow freely. With such an arrangement the capacity of the grinder or grinders must be adequate to charge the cooker in less than five minutes.

**Special equipment.** European manufacturers of process cheese have favored the use of mills and mixers after the grinders to prepare the cheese for the heating operation. The mill has three adjustable rollers made of porphyry or granite. These rollers rotate against each other and one of them also has a sideways motion. Water, color and emulsifiers are mixed with the cheese in the mill. Some of the larger plants use a special mixing machine after the cheese has gone through the grinder and mill. Some of this equipment is being used by a few American manufacturers who are interested in processing the foreign types of cheese.

## EMULSIFIERS

**Purposes of using emulsifiers.** The commercial manufacture of process cheese depends largely upon the use of certain salts which tend to prevent the separation of fat from the cheese during the heating operations. These salts are commonly called **emulsifiers.** They have a solvent action upon the cheese proteins and they cause specific characteristics in the body and texture of the finished product. Some blends of cheese can be processed without fat separation even when emulsifying agents are not used. The salts are generally used, however, to produce desirable melting and slicing properties in the finished cheese.

**Action of emulsifiers.** The two most commonly used emulsifiers are di-sodium phosphate and sodium citrate and mixtures of these salts. Used to a lesser extent are Rochelle salts, sodium pyrophosphate and sodium metaphosphate (Sommer and Templeton, 1939).

Templeton and Sommer (1930, 1932) investigated the use of common emulsifiers. They observed that di-sodium phosphate produced a weaker body than sodium citrate. When di-sodium phosphate was added to the cheese with sodium citrate the body of the finished cheese was weaker than was obtained with the citrate alone. They could not explain the differences in body obtained with the emulsifiers by variations in the reaction of the cheese. They observed that cheese made with sodium citrate retained small air cells and that cheese without these air cells was coarse in body. They found that increasing amounts of Rochelle salts tended to make the cheese brittle, mealy, and poor in slicing properties. They found that the two forms of sodium citrate, U.S.P. VIII ($2Na_3C_6H_5O_7 \cdot 11H_2O$) and U.S.P.X. ($Na_3C_6H_5O_7 \cdot 2H_2O$), acted alike in processing cheese.

Sommer (1930) observed grittiness in processed cheese and identified the crystals as calcium tartrate. He calculated that the solubility of calcium tartrate was such that, when Rochelle salts were used in process cheese, crystallization of the calcium tartrate always occurred. Sommer argued that the detection of sandiness in the cheese really depended only upon the size of crystals.

Sommer and Templeton (1939) reported that many salts had been proposed for use in processing cheese. They listed sodium citrate, sodium tartrate, sodium-potassium tartrate (Rochelle salts), ammonium tartrate and ammonium chloride, di-sodium ortho-phosphate ($Na_2HPO_4$), tri-sodium ortho-phosphate ($Na_3PO_4$), sodium metaphosphate ($NaPO_3$), tetra-sodium pyrophosphate ($Na_4P_2O_7$), sodium polyphosphates (e.g. $Na_5P_3O_{10}$), lactates, mucates, malates, and gluconates.

**Choosing emulsifiers.** Sommer and Templeton (1939) suggested that the choice of emulsifying salt depended on cost and such factors as quality and melting properties of cheese desired. They pointed out that (1) sodium metaphosphate made process cheese more acid in flavor; (2) when used at the rate of 2%, sodium citrate, Rochelle salts, di-sodium phosphate and tetra-sodium pyrophosphate showed satisfactory results with a wider variation in blends than the other salts mentioned above. They found that Rochelle salts or di-sodium phosphate produced cheese with better melting properties than that produced with sodium metaphosphate and tetra-sodium pyrophosphate.

## PROCESS CHEESE KETTLES

**Steam-jacketed kettle.** Process cheese for many years has been made in up-right, steam-jacketed kettles equipped with double acting agitators. European manufacturers in the past have used this type of equipment but generally have the kettles closed and equipped to permit the use of vacuum or pressure to aid in heating and emptying the machine. This modification of the equipment makes it possible to heat the cheese with direct steam and then to remove excess moisture from the hot cheese by applying a vacuum. Steam-jacketed kettles range in size from the small, laboratory style capable of holding only a few pounds, up to machines which handle several hundred pounds at one time. Kettles with capacities of 200 to 400 pounds are commonly used. Such amounts of cheese must be removed rapidly from the kettles so that especially wide gates are provided. Provisions are made in some of the largest types of foreign makes of machines to hasten this operation by applying air or steam pressure to the closed kettles to force the semi-fluid cheese out of the bottom of the kettle at a more rapid rate.

**Horizontal cookers.** Wheeler and Scott (1925) developed a type of cooker which embodied a radically different design than the machines which have been described. Machines of similar design are now generally used in the processing industry where cheese is processed on the large scale. The body of this type of machine is horizontal and cylindrical or trough-like in shape. It is closed at both ends. The cheese is stirred with one or sometimes two screw- or spiral-shaped, horizontally acting conveyors. The cheese enters at the top and rear of the kettle. It is forced toward the gate end of the machine by the conveyors; at the same time, steam is injected into it. As the charge of the kettle approaches its capacity, the partially melted cheese flows back over the agitators so that complete mixing and thorough heating of the batch is accomplished in a minimum of time. The complete cycle of the operation of this type of kettle, including filling, heating, stirring and emptying, may be as short as six minutes. Rapid emptying of these kettles is accomplished by the positive delivery action of the screw- or spiral-shaped conveyors which force the melted cheese through the wide-mouthed gate at the end of the kettle opposite the hopper.

## PROCESSING

The several operations concerned with the treatment of the ground cheese during heating, stirring, and emptying of the process cheese kettle are sometimes known as **processing.** The operations involved are the addition of water, color, emulsifiers, and the heating, stirring, and emptying of the kettle

**Adding emulsifiers.** Emulsifiers are added to the cheese in several ways. They may be added as the cheese is placed in the hopper of the grinder; this insures intimate mixing before the cheese falls into the cheese kettle. The salts may be added to the cheese during the heating process; the cheese is partly melted at this time and the salts are quickly incorporated if they are of the soluble type. If water is to be added, the salts are sometimes mixed with it and placed in the kettle before or after the cheese is introduced.

**Amount of emulsifiers.** The amount of emulsifier used varies from 0.5 to 3% of the weight of the cheese, depending upon such factors as the type of blend, acidity, composition, and variety of cheese, and upon the identity of the emusifying salts. The combined effects of these factors is sometimes difficult, if not impossible, to estimate. When there is some doubt concerning such combinations, it is customary in some plants to make small, trial batches of two or three pounds in much the same manner as evaporated milk manufacturers make test runs to determine the correct treatment to control the viscosity of their sterilized milk. By such trials the most favorable amounts and combinations of available emulsifiers can be determined for the particular blend in question. Manufacturers of process Cheddar cheese rarely choose to make such trials. Instead, they depend upon the skill and judgment of the blender to achieve uniformity of processing properties. The ordinary emulsifiers, like sodium citrate and di-sodium phosphate, are most commonly used at the rate of 1 to 2% of the weight of cheese in the batch.

**Adding water and color.** The small amount of color, which is sometimes required to obtain uniformity in the finished product, can be easily added with the water required for standardizing the moisture content of the cheese. In large batches the color is commonly diluted and incorporated as the first of the batch enters the kettle.

Some manufacturers make careful calculations to determine the amount of water that must be added to each batch in order to obtain the maximum yield and uniformity of product. Others regulate moisture content by blending to obtain uniformity in the finished product. By either method, allowance must be made for moisture incorporated by injection of steam during the heating of the cheese. Both methods of regulation require accurate knowledge of the moisture content of the cheese in the blend. Frequent and regular checks on the moisture content of the process cheese are made during the processing operations to detect and control variations. These moisture tests are usually made with a drying lamp. More accurate tests are made later on the packaged cheese.

TABLE 23:1. SUMMARY OF WEIGHTS AND COMPOSITIONS FOR THE BLEND

| *Number* * | *Vat lot* | *Weight* | *Dry Matter* | | *Fat* | |
|---|---|---|---|---|---|---|
| | | *lb.* | % | *lb.* | % | *lb.* |
| 1 | A | 72 | 62 | 44.6 | 32 | 23.1 |
| 2 | B | 75 | 64 | 48.0 | 33 | 24.7 |
| 3 to 31 | C to X | etc. | etc. | etc. | etc. | etc. |
| 32 | Y | 70 | 67 | 46.9 | 34 | 23.8 |
| Blend totals | | 2336 lb. | | 1520 lb. | | 820 lb. |
| Batch totals | | 584 lb. | | 380 lb. | | 205 lb. |

* Data on numbers 3 to 31, vat lots C to X, inclusive, are omitted from the table for the sake of brevity; they are included in the blend totals and batch totals.

Table 23:1 summarizes data which might have been obtained from a typical blend of cheese such as was illustrated in figure 23:1. It is assumed that 32 different cheddars from as many vat lots make up the blend. The blending record, of which only a portion is produced in table 23:1, shows for each lot of cheese, its weight after cleaning, dry matter and fat contents. The total weight of the 32 cheese in the blend equals 2336 pounds, the amount of dry matter, 1520 pounds, and the fat content, 820 pounds. Table 23:2 summarizes the results of the calculations which determine the amounts of emulsifier, salt, and water to be added to each batch. Emulsifier, added at the rate of 2% of the weight of cheese, is 11.7 pounds; salt, required at 0.5% of the cheese equals 2.9 pounds. Steam required to heat 100 pounds of cheese from the initial temperature of 65° F. to the

TABLE 23:2. SUMMARY OF AMOUNTS OF EMULSIFIER, SALT, AND WATER REQUIRED BY THE BATCH

| *Ingredient* | *Weight* | *Dry matter* | *Fat* |
|---|---|---|---|
| | *lb.* | *lb.* | *lb.* |
| Cheese in batch | 584 | 380 | 205 |
| Emulsifier (2% of cheese) | 11.7 | 8.8 | 0 |
| Salt (0.5% of cheese) | 2.9 | 0.0 | 0 |
| Condensate * (5.5% of cheese) | 32.1 | 0.0 | 0 |
| Totals in batch | 630.7 | 388.8 | 205 |
| Water to give 40% moisture | 17.3 | | |

* It is assumed that cheese has a specific heat of 0.61, and that the temperature of the cheese is increased from 65° to 150°F. by steam injection heating. Condensate necessary to give this 85°F. increase in temperature approximates 5.5 pounds per 100 pounds of cheese.

final cooking temperature of 150°F. is calculated to be 5.5 pounds or 5.5% of the weight of the cheese; this adds 32.1 pounds of water and gives a total weight of 630.7 pounds for the amount of products in the kettle. The amount of dry matter in the cheese, plus emulsifier, and salt total 388.8 pounds. The desired dry matter content of the finished cheese is 60% (40% moisture) so that the total weight of the finished batch must equal 648 pounds (388.8 lb. dry matter ÷ 0.60 = 648 lb. of finished product with 40% moisture). The difference between 648 pounds and the combined weights of cheese, emulsifier, salt and condensate, or 630.7 pounds, equals 17.3 pounds of water which must be added to standardize the batch (648 lb. finished cheese–630.7 lb. batch = 17.3 lb. water for standardizing).

A certain amount of water is lost by evaporation during the heating and stirring of the cheese. The amount of this loss depends on such conditions as type and size of kettle, exposure of the cheese to the air during heating, amount of cheese in the kettle, and duration of heating. These conditions remain fairly constant from batch to batch. Frequent tests are made for moisture in the packaged cheese; the results are used to determine the water required to compensate for evaporation. The experienced operator determines in this way the approximate adjustments required under his conditions of manufacturing.

**Heating treatments.** The heating and melting of the cheese are accompanied by a series of changes that depend on the speed of heating, rate of agitation, temperature attained, and duration of heating.

The speed of heating in modern cookers is much faster than in the older steam-jacketed types; new methods of agitation and efficiency of heating with direct steam are chiefly responsible. A large kettle of the steam-jacketed type may require 30 minutes to heat the batch of cheese. An efficient horizontal cooker, in which steam is injected directly into the cheese, may require only 3 to 5 minutes to complete heating.

The optimum temperature for heating Cheddar cheese in processing approximates 150° F. Templeton and Sommer (1930, 1932) found that temperatures less than 140° F., were sometimes associated with gas formation in the finished cheese, while those higher than 150° F. produced increased firmness in the product which might be undesirable. Barker (1941a) advised heating to about 160° F. but stated that different blends required different temperatures. Temperatures of 160° to 190° F. are commonly used in processing the softer varieties of cheese and cheese spreads. The keeping properties of these products are improved by the use of the higher temperatures of heating.

The period of holding the cheese in the cooker at the optimum temperature for heating is usually determined by the physical characteristics of the cheese. The time is not longer than 2 to 5 minutes in the fastest operations; the period is extended if the condition of the cheese demands further agitation. No attempt is made to duplicate the pasteurizing procedures used for fluid milk. The slow cooling of the cheese after the maximum temperature is attained assures adequate time at temperatures in the pasteurizing range. Templeton and Sommer (1930) observed that holding cheese at temperatures between 140° and 155° F. increased the firmness at a rate which was almost directly proportional to the holding time, when that was between 3 and 10 minutes. Some moisture was lost during this period of holding and agitation; this accounted for part of the increased firmness. When process cheese is held in the kettle at high temperatures for an extended period of time, the color tends to deepen. Price (1929) observed that cheese which accumulated on the sides of the kettle tended to darken the color of subsequent batches.

**Changes during heating.** Heat is applied to the cheese in the kettle as soon as there is enough of it present to absorb the live steam injected, or to prevent burning on the heating surfaces if the steam-jacketed type of kettle is used. When the heat is first applied the cheese becomes sticky and tends to gather in clumps or balls. This condition is minimized by efficient agitation and the cheese disperses to form a rough appearing mass.

Fat may separate at this stage of heating. The care exercised in selecting the cheese for the blend becomes apparent at this point in processing; a proper blend may show no visible fat separation. At about 130° F. the free fat, if any is present, begins to be absorbed. As the temperature approaches 150° F. the cheese becomes more plastic and ductile; long, thin strings of hot cheese can be drawn from the batch with a spatula; the batch appears smooth, homogeneous, and glossy, somewhat like creamed butter; it flows readily but has a high viscosity at this stage of processing. The attainment of these physical characteristics indicates that the heating process is complete and the batch is ready to be drawn from the kettle.

## Packaging and Cooling

In large scale operations the cheese is conveyed or piped to the package filler; in small scale operations the cheese is drawn directly from the kettle into the final package. The cheese must be kept hot and should be stirred as long as the semifluid condition is needed for satisfactory packaging.

Packaging machinery is an essential part of large scale operations. Elaborate devices are available when operations are large enough to afford them. This equipment measures the cheese into packages of various sizes and shapes. Auxiliary equipment folds and lines boxes, moves them to the filler, closes and seals the wrappers, covers the boxes, and conveys them to the shipping cartons. Much of this elaborate equipment has been designed and constructed by the manufacturers who use it. Some of it is now available for more general use. Some packaging operations are only partly mechanized; hand labor is then used for such operations as lining boxes, closing wrappers over the hot cheese, and covering the boxes.

Packaging process cheese by hand is a laborious procedure. Such operations are usually, but not always, limited to boxes weighing 2 pounds or more. The processing kettle itself may serve as filling machine. It maintains the proper temperature and furnishes agitation while the batch is slowly drawn through a hand operated, wide-mouthed gate in the kettle. Small scale equipment to facilitate the filling operation is gradually appearing on the market.

The packaged cheese is boxed or placed in cartons and moved to the cooling room. Large, 5-pound boxes are not bundled until they have reached room temperature. The packages are stacked to permit free circulation of air to facilitate cooling. The cooling room temperature approximates 65° to 70 F. Packages are not placed under refrigeration until they have slowly cooled to these temperatures.

As the cheese cools it first assumes a soft plastic consistency. Gradually it becomes firmer as it cools. At room temperature it attains a consistency which closely resembles that of natural cheese of comparable quality and composition. After the product has been chilled in the refrigerator it shows an additional firmness which is caused by the solidification of the fat. This is somewhat comparable to the hardening of butter after churning.

## Packages and Wrappers

Packages for process Cheddar cheese range in size from 8 ounces to 5 pounds. The 2-pound package is a popular size for home use. The 5-pound unit is commonly used for slicing purposes in stores and restaurants. Cardboard boxes lined with a suitable wrapper are used for all sizes. Metal cans are used for export or when the cheese is to be subjected to rough handling without refrigeration; such cans vary in size from a few ounces to 7 pounds.

Wrappers or liners for containers vary with the type of package. Cans are lined with parchment chiefly to facilitate the removal of the product. Cardboard and wooden boxes for many years were lined with tin foil and aluminum foil. The tin foil discolored under certain conditions. Templeton and Sommer (1937) noticed that the phosphate salts in Cheddar cheese tended to accelerate the darkening of tin foil especially when the pH was more alkaline than 5.8. They preferred tin foil to aluminum foil but stated that the latter, when coated, might be more suitable and economical for some types of cheese. Manufacturers experienced some difficulties in substituting aluminum for tin foil in packaging machines. Shortage of both metals stimulated search for other types of wrappers and now the use of metal foils has been discontinued except for the packaging of small specialties, like individual services of some varieties of process cheese.

The type of wrapper now most commonly used for process Cheddar cheese is better in some respects than the metal foil it replaced. It is a transparent cellulose sheet coated with a waxlike compound on the side of the wrapper that touches the cheese. When it is cold the wrapper is semitransparent; when it touches the hot cheese the wax-like compound melts enough to become transparent. This type of wrapper imparts no off flavor to the surface of the cheese, it clings to the cheese very well yet separates from it cleanly. It is practically moisture-proof; it stands storage very well at low temperatures and fairly well at high humidities and high temperatures. It can be heat-sealed readily.

This type of wrapper is used in the form of pouches and sheets. Pouches are commonly used for the 2-pound and 5-pound loaves; the sheets are better adapted to smaller packages that are handled entirely by machine.

## PROCESS CHEESE FOODS AND PROCESS CHEESE SPREADS

The properties of process cheese can be changed by the addition of other food products such as cream, milk, skim milk, and whey, or their concentrates, and by the addition of fruits, vegetables and meats. Such products are classified as process cheese foods or process cheese spreads. They are characterized by mild cheese flavors, and by a soft consistency at room temperature.

### Proposed Standards

The Federal Security Agency (1947) published proposed standards and definitions which reflect trends of industrial practices as well as the probable form of regulations which may be adopted eventually. These proposed standards may be modified in whole or in part before they reach their final form as legal standards.

**Pasteurized process cheese foods.** According to the proposed definitions a cheese food is made in the same manner as pasteurized process cheese. The product contains one or more varieties of cheese and the cheese ingredients constitute not less than 51 per cent of the weight of the finished food. Emulsifying substances are limited to 3 per cent of the weight of the finished food; acids are limited to the amounts necessary to produce a pH of 5.0. The product may be smoked or may contain the ingredient prepared by condensing or precipitating wood smoke. Spice or flavor may be used if the effect does not simulate the flavor of aged cheese. The emulsifying salts and acids listed as optional ingredients are identical to those permitted in process cheese. Cream, milk, skim milk, or whey, or any of these products from which water has been removed, may be added alone or together. Water, salt, and coloring are permitted. The finished cheese food contains not over 44 per cent moisture and not less than 23 per cent fat. A leniency of 1 per cent in fat and moisture requirements is suggested when the food is prepared with cooked, canned, or dried fruit, or vegetable, or properly prepared cooked or canned meat.

**Pasteurized process cheese spreads.** These products according to the proposed definitions of the Federal Security Agency (1947) conform to the definition of process cheese foods except for differences in fat, moisture, sweetening agents, and water-retaining substances. They contain more than 44 per cent moisture but not more than 60 per cent; the fat content is not less than 20 per cent. They may contain one or more of certain water-retaining substances in amounts not in excess of 0.8 per cent of the weight of the finished food. The optional water-retaining substances are: carob bean gum, gum karaya, gum tragacanth, gelatin, carboxymethyl cellulose, algin, guar gum, carrageenin, and oat gum. Sweetening agents permitted include: sugar, dextrose, maltose, corn-sirup solids and hydrolyzed lactose. Like cheese foods, these products may contain properly prepared fruits, vegetables, or meats.

## Manufacturing Process Cheese Foods and Spreads

**Blending.** The selection of numerous vat lots of cheese for quality control is as desirable for the soft types of process cheese as for the harder types. Flavor, body, and composition are modified and controlled by the cheese in the blend and by the addition of cream, and concentrates of whey and skim milk.

Davel and Retief (1928) found that cured Cheddar cheese with titratable acidity in the higher range, with 1.9 per cent acidity as the maximum, gave a spreading body. Templeton and Sommer (1934) reported that aged cheese in cheese spreads gave better flavor but that very old cheese was likely to produce grainy body; very young cheese gave a product too rubbery to spread.

Two or more varieties of cheese are often combined in the making of the soft types of process cheese. One variety, like Cheddar or Cream cheese, provides the bulk of the product. Another variety of cheese or other substances are added for flavor. There is little or no experimental evidence to show ideal combinations of cheese or the effects of variations in blends of cheese. Some information on the art of manufacturing has been given in popular discussions by Barker (1940, 1940a, 1942, 1947a).

TABLE 23:3. ANALYSES OF FIVE COMMERCIAL CHEESE SPREADS
(Data from Sommer and Templeton, 1939)

| *Sample* | *Moisture* | *Fat* | *Fat in dry matter* | *Lactose* |
|---|---|---|---|---|
| | % | % | % | % |
| 1 | 41.13 | 30.60 | 52.08 | 2.13 |
| 2 | 43.38 | 25.48 | 45.00 | 5.39 |
| 3 | 44.19 | 25.63 | 45.92 | 6.75 |
| 4 | 44.89 | 25.16 | 45.65 | 4.28 |
| 5 | 44.05 | 33.27 | 59.46 | 4.20 |

**Fat and moisture adjustments.** These adjustments affect the body characteristics. Table 23:3 shows analyses of commercial products. Templeton and Sommer (1932a) attempted to produce desirable soft consistency by increasing the fat and moisture contents of the product. They found that when the moisture content was excessively high the body of the product was mealy. This mealiness could be corrected by increasing the fat content of the mixture but too much fat gave an excessively soft consistency. Their mixtures contained 10 parts of whey powder, 2 parts of sodium citrate, 0.5 parts of common salt, and 87.5 parts of Cheddar cheese, cream and water. The last three substances were proportioned to give the desired amounts of fat and solids-not-fat in the batch.

**Whey and skim milk concentrates.** Dried whey and dried skim milk are common ingredients used in the making of these products. They contribute valuable nutritive elements to cheese foods and spreads. Whey concentrate, dried or condensed, is used because it contributes an inexpensive form of milk solids, it produces soft body, and because it adds distinctive flavor. It restores to the cheese some of the milk solids lost in the normal manufacturing operation. Templeton and Sommer (1934) reported that dried whey produced softer body in cheese spreads than skim milk powder.

Dried whey and dried skim milk are rich in lactose. Lactose constitutes approximately 65 per cent of the weight of dried whey and 50 per cent of dried skim milk. The amounts of these products used in processed cheese foods cannot exceed certain limits without the possibility of causing the formation of lactose

TABLE 23:4. PROXIMATE AMOUNTS OF DRIED WHEY OR DRIED SKIM MILK THAT GIVE SATURATED SOLUTIONS OF LACTOSE IN CHEESE FOODS AND SPREADS AT 60°F.

| *Moisture in cheese product* | *Maximum permissible percentages of concentrates * in cheese foods and spreads* | |
|---|---|---|
| | *Dried whey *** | *Dry skim milk **** |
| % | % | % |
| 40 | 10.4 | 13.5 |
| 45 | 11.7 | 15.2 |
| 50 | 13.0 | 16.9 |
| 55 | 14.3 | 18.6 |
| 60 | 15.6 | 20.3 |
| 65 | 16.9 | 22.0 |

* These maximum amounts of concentrates are not necessarily recommended for any blend; other factors than lactose concentration must be considered.

** Estimated lactose concentration in dried whey is 65%.

*** Estimated lactose in dry skim milk is 50%.

crystals. Table 23:4 has been calculated to show approximate amounts of dried whey and dried skim milk that will contribute enough lactose to form saturated solutions of this sugar in cheese foods with different moisture contents. The use of these maximum amounts is not recommended. Since these concentrates are sometimes used together in cheese foods it is pertinent to observe that 1.3 pounds of dry skim milk provides essentially the same amount of lactose as 1 pound of dried whey; 0.77 pounds of dried whey contains the same amount of lactose as 1 pound of dried skim milk.

**Acidity control.** The reaction of the cheese food or cheese spread affects its keeping properties. The addition of cream, dry skim milk, and water tends to make the cheese mixture less acid and consequently a more favorable medium for the growth of some gas forming types of organisms. Albus and Ayers (1928) called attention to such defects in reheated cheese to which pimentos had been added. Templeton and Sommer (1932) recommended a reaction of about 5.8 to 6.1 pH and advocated the addition of enough citric acid to attain this level. These values were determined by measurements made on suspensions of one part of cheese in ten parts of water. A later paper by these same authors (1937) suggests that such measurements were approximately 0.45 pH units higher than comparable measurements of undiluted samples of cheese. In order to obtain the most desirable keeping properties it is advisable to maintain a minimum acidity of approximately 5.4 pH in the manufactured products. Acidification is accomplished with citric acid or some of the other acids which are listed in the tentative definitions of the Federal Security Agency (1947).

**Temperatures of heating.** Higher temperatures of processing and packaging are used for cheese foods and spreads than are commonly used for the hard types of process cheese. These higher temperatures give improved keeping properties to these more perishable products. Templeton and Sommer (1932) recommended temperatures of 160° to 180°F. to destroy heat resistant and putrefactive organisms. These organisms, they pointed out, were introduced by the addition of sweet cream to the batches and their growth was encouraged by low acidity of the cheese spreads.

**Homogenizing.** Homogenizing of the hot batches is sometimes practiced in the manufacture of cheese foods or spreads in which high moisture contents and fluidity make this procedure feasible. This treatment produces extremely smooth consistency in the finished product. It is particularly valuable when large amounts of Cream cheese curd or sweet cream are used in the blend. Pressures of 1000 to 3000 pounds are used in homogenizing; the higher pressures produce heavier body in the finished product.

The use of the homogenizer introduces a possibility of contamination in the manufacture of cheese spreads. The machine should be carefully taken apart and cleaned after each run. It should be sterilized by pumping water through it at 160°F. immediately before it is used.

**Packaging.** Cheese foods, which normally contain less than 44 per cent moisture, have a consistency that permits packaging in the same types of wrappers and boxes used for process cheese. These products are being sold in 5-, 2- and ½-pound packages. Cheese spreads, which normally contain over 44 per cent moisture, are commonly packaged in glass containers with a vacuum-sealed closure.

**Geneva Cream Cheese.** Dahlberg and Marquardt (1934) described the manufacture of a unique and excellent spread which they called "Geneva Cream Cheese." Their method of manufacture consisted of solidification by homogenization of a hot, pasteurized mixture of 5 pounds of dry skim milk, 93 pounds of 40 to 42 per cent sweet cream, 0.5 pounds of ground agar, and 0.75 pounds of salt. This mixture was first pasteurized at 180° to 185°F. for 5 minutes, cooled to 110°F., inoculated with 0.75 pounds of lactic starter, and homogenized at 3,500 pounds pressure. The plastic material delivered by the homogenizer was placed directly in the package, chilled, and then incubated at 72°F. to develop acid flavor. This procedure was modified to obtain a spread flavored with Cheddar or Roquefort cheese by dispersing 25 pounds of aged Cheddar, or 15 pounds of Roquefort, in the hot cream, with or without emulsifying salts. The usual 5 pounds of dry skim milk, 0.75 pounds of salt, and enough sweet cream with 40 to 42 per cent fat were used to make the total weight of the batch equal 100 pounds. Ground agar was added when better slicing properties were desired.

The legal status of the products made by the Geneva method is not clear. The definition of the Federal Security Agency (1942) specifically mentioned draining of the coagulated material as an essential step in the making of Cream cheese. The Geneva Cream cheese spread is not drained at any stage of manufacture. The blends made with Cheddar and Roquefort cheese contain less than the 51 per cent of cheese mentioned as a requirement for a cheese food or cheese spread in the proposed definitions of the Federal Security Agency (1947). It seems probable that labeling of this product for merchandising should be developed according to the advice of food regulatory agencies until its status in commerce has been clearly recognized.

## REFERENCES

Albus, W. R. (1928). J. Bact., *15,* 203.

Albus, W. R. and Ayers, S. Henry (1928). J. Dairy Sci., *11,* 175.

Babel, F. J. and Hammer, B. W. (1945). J. Dairy Sci., *28,* 201.

Barker, C. R. (1939). Nat. Butter and Cheese J., *30,* No. 12:14.

Barker, C. R. (1940). Nat. Butter and Cheese J., *31,* No. 6:26.

Barker, C. R. (1940a). Nat. Butter and Cheese J., *31,* No. 8:64.

Barker, C. R. (1941). Nat. Butter and Cheese J., *32,* No. 8:14.

Barker, C. R. (1941a). Food Ind., *13,* No. 12:53.

Barker, C. R. (1942). Nat. Butter and Cheese J., *33,* No. 5:14.

Barker, C. R. (1946). Nat. Butter and Cheese J., *37,* No. 12:90.

Barker, C. R. (1947). Nat. Butter and Cheese J., *38,* No. 1:42.

Barker, C. R. (1947a). Nat. Butter and Cheese J., *38,* No. 4:50.

Brickner, Simon (1942). Food Ind., *14,* No. 3:47.

Dahlberg, A. C. and Marquardt, J. C. (1934). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 226.

Davel, H. B. and Retief, D. J. (1928). New York Produce Review and American Creamery, *65,* 384.

Erekson, A. B. (1946). Nat. Butter and Cheese J., *37,* No. 7:41.

Federal Security Agency (1947). Federal Register, *12,* No. 37:1192.

Food and Drug Administration (1942). Federal Register, *7,* 10755, 10835.

Hanson, F. E., Spicer, D. W. and Price, W. V. (1938). J. Dairy Sci., *21*, 433.

Hobson, A. and Schaars, M. A. (1935). Wis. Agr. Expt. Sta., Res. Bul. 128.

Kraft, J. L. (1916). U. S. Patent 1,186,524. (June 6, 1916).

McDowall, F. H. (1931). New Zealand J. Sci. and Technol., *12*, No. 4:215.

Palmer, J. L. and Sly, W. H. (1943). Dairy Indus., *8*, No. 8:427.

Price, Walter V. (1929). J. Dairy Sci., *12*, 377.

Price, W. V. (1946). Nat. Butter and Cheese J., *37*, No. 7:40.

Sanders, George P. and Sager, Oscar (1946). J. Dairy Sci., *29*, 737.

Sommer, H. H. (1930). J. Dairy Sci., *13*, 288.

Sommer, H. H. and Templeton, H. L. (1939). Wis. Agr. Expt. Sta., Res. Bul. 137.

Templeton, H. L. and Sommer, H. H. (1930). J. Dairy Sci., *13*, 203.

Templeton, Hugh L. and Sommer, H. H. (1932). J. Dairy Sci., *15*, 29.

Templeton, H. L. and Sommer, H. H. (1932a). J. Dairy Sci., *15*, 155.

Templeton, H. L. and Sommer, H. H. (1934). J. Dairy Sci., *17*, 373.

Templeton, H. L. and Sommer, H. H. (1937). J. Dairy Sci., *20*, 231.

Wheeler, J. H. and Scott, H. M. (1925). U. S. Patent 1,523,678 (Jan. 20, 1925).

# CHAPTER 24

# COTTAGE CHEESE

**Cottage cheese** is a soft, unripened cheese that is usually made from skim milk. It may be made from reconstituted, concentrated skim milk or dried skim milk. It has a mild, acid flavor. It consists of small particles or flakes of curd which have a meaty consistency. The particles may be as small as kernels of wheat but they are more commonly as large as a somewhat flattened, pitted cherry. The freshly made curd looks like popped kernels of corn. In some markets this curd is known as **Pot cheese.**

Cottage cheese is usually mixed with cream or mixtures of cream and milk or skim milk. When the mixture contains not less than 4% fat it is called **creamed Cottage cheese.**

When Cottage cheese is made in large flakes by the use of rennet, large knives, and liberal amounts of water to reduce the acid flavor, the product is known as **low-acid, sweet-curd, rennet-type,** or **flake-type Cottage cheese.** This product is very popular in critical markets. It is probably responsible for the rapidly increasing production and use of Cottage cheese in the United States.

## PRODUCTION OF COTTAGE CHEESE

The annual production of Cottage, Pot, and Baker's cheese is increasing more rapidly than that of any other type of cheese in the United States. Baker's cheese is described in Chapter 25. In the 20 year period ending in 1940 the annual production of Cottage, Pot, and Baker's cheese increased over six fold. In 1940 168,851,000 pounds were produced in the United States; in 1945 the amount was 284,774,000 pounds.

The United States Department of Agriculture, Bureau of Agricultural Economics in 1946 for the first time reported separately the production of Cottage cheese curd and creamed Cottage cheese. Cottage cheese curd production totaled 251,699,000 pounds while creamed Cottage cheese produced was 209,945,-

000 pounds. These production figures cannot be added together to give the total production. Some Cottage cheese reported was sold directly to the consumer; some of it, however, was sold to distributing plants where it was creamed. The distributors and manufacturers then reported on the production of the same curd.

States leading in the production of Cottage, Pot, and Baker's cheese in 1946 were New York with 45,260,000 pounds and California with 39,779,000 pounds. California was first in the production of creamed Cottage cheese with 57,445,000 pounds while Ohio was second with 21,034,000 pounds.

Production of Cottage, Pot and Baker's cheese shows considerable seasonal variation. Production is restricted when skim milk for manufacturing purposes is short in late fall and early winter. Production in May and June, when demand is good and milk is plentiful, is almost double that of November and December, when skim milk is scarce. Production data for the months of 1946 are shown in table 24:1.

TABLE 24:1. COTTAGE, POT AND BAKER'S CHEESE * PRODUCTION IN THE UNITED STATES DURING EACH MONTH OF 1946
(U. S. Department of Agriculture, 1948)

| *Month* | *Weight* | *Per cent* | *Month* | *Weight* | *Per cent* |
|---|---|---|---|---|---|
| | (1000 lb.) | | | (1000 lb.) | |
| Jan. | 18,103 | 7.2 | Jul. | 23,390 | 9.3 |
| Feb. | 18,756 | 7.4 | Aug. | 19,611 | 7.8 |
| Mar. | 23,778 | 9.4 | Sep. | 18,596 | 7.4 |
| Apr. | 24,644 | 9.8 | Oct. | 18,675 | 7.4 |
| May | 27,588 | 11.0 | Nov. | 15,677 | 6.2 |
| Jun. | 27,857 | 11.1 | Dec. | 15,024 | 6.0 |
| | | | Total | 251,699 | 100.0 |

* Cheese containing less than 4% fat.

## VARIATIONS IN METHODS OF MAKING COTTAGE CHEESE

There are two factory methods used in the making of Cottage cheese. Each of these methods is varied to produce the proper curd formation to begin the operations of cutting and heating in approximately 4 or 16 hours. In the first of these factory methods, the milk is coagulated by acidity developed by the action of lactic starter. In the second method, coagulation is accomplished by the combined actions of lactic starter and a small quantity of rennet. The method and variation in time of coagulation are determined by consumer preferences, manufacturing facilities, and labor management policies.

**Acid curd.** Cottage cheese made without rennet usually, but not always, consists of small granules or particles of curd. In the making operations the whey is easily expelled from the curd with a minimum of heating. The curd must be skillfully handled because the particles tend to mat together during heating. This often causes excessive breakage, greater curd losses in the whey, and consequently, reduced yield. The flavor of the Cottage cheese produced by this method may be extremely acid if the curd is not washed with water, or it may be mildly acid and pleasant in flavor if it is thoroughly washed.

**Rennet-curd.** Cottage cheese made by the combined action of acid and rennet is very popular in some of the most critical markets. It is mild in flavor and is usually made so that it consists of large flakes or particles of curd. The body is meaty but not tough or rubbery; it is free from hard gritty particles. Because of these characteristics, this cheese is commonly known as low-acid, sweet-curd, or flake-type Cottage cheese. The rennet used in making the cheese is partly responsible for the desirable flake formation. The rennet produces a firm curd which can be cut easily into the large cubes necessary to form these flakes. Phillips (1944) observed that the rennet is particularly effective for proper curd formation when the flash-heating system of pasteurizing is used. Thurston and Gould (1933) stated that the rennet tends to prevent matting of the curd during heating. Prevention of matting preserves the original flakes of curd.

**Short-setting.** When the interval is 4 to 6 hours from the adding of the starter, or starter and rennet if both are used, until the time of cutting, the process is called the **short-setting** procedure. The 4 to 6 hour period for coagulating the milk is achieved by using a setting temperature of 85 to 90°F. and increasing the amount of starter to 4 or 5 per cent. This process is popular when milk storage space is lacking, when it is desirable to make efficient use of labor during that part of the day when other plant activities tend to decrease, and when it is desirable to convert the milk into curd for the earliest possible shipment from the plant. It is preferred by some operators who find that this short-setting process gives them better control of the making operations. This is possible because acidity measurements can be made more frequently during the time of coagulation. Acidity control is essential for maximum quality and yield in either process of manufacture, but it must be followed very carefully in the short-setting process because it changes more rapidly.

**Long-setting.** When the time allowed for coagulation approximates 16 hours, the procedure is known as the **long-setting** process or, frequently, the **overnight** process. In this procedure the setting temperature is 72°F., the optimum for the development of flavor by the lactic starter. Starter is used at the rate of 0.3 to 1 per cent. This method is usually preferred when the curd-making operations can be performed in the morning without interfering with other plant operations.

Differences in quality of cheese produced by the long- and short-setting processes are negligible, providing proper manufacturing procedures are used. Yields by the short-setting process tend to be slightly higher, probably because the time of cutting is more closely watched and the curd is more likely to be at its optimum acidity and curd strength. Such control in either process results in less breakage of curd in the making operations.

## Milk for Cottage Cheese

Fresh, clean-flavored skim milk of low bacterial content is necessary for the production of Cottage cheese of superior quality and keeping properties.

**Pasteurization.** The skim milk is pasteurized immediately after separation. Pasteurization is essential for the manufacture of a commercially acceptable product. It establishes control over the fermentation process and produces a more uniform product of better quality and keeping properties. Pasteurization of the milk is an added assurance of the healthfulness of the finished product.

The holder method of pasteurizing at 143° to 145°F. for 30 minutes is recommended because it promotes the formation of the most desirable curd. The high-temperature, short-time pasteurization at 160°F. for 15 to 20 seconds is usually entirely satisfactory although difficulties have been observed with some milk supplies. Excessive heating of the milk causes soft curd formation. Such curd is easily broken in cutting and handling; it is difficult or even impossible to firm it properly in the heating process. Manufacturing losses are excessive, and the quality of cheese from overheated milk is inferior.

Board of Health regulations in most of the important markets require the use of properly pasteurized milk. The definitions of the Food and Drugs Administration specify that only pasteurized skim milk, milk and cream can be used in the making of Cottage cheese to be shipped in interstate commerce.

## STARTER FOR COTTAGE CHEESE

It is essential to use a lactic starter of high quality in commercial manufacture of Cottage cheese from pasteurized milk. The procedures for making and the characteristics of such starter are described and discussed in Chapter 9.

Some manufacturers prefer to use skim milk for making starter for Cottage cheese. This is a desirable practice. When starter made from whole milk is used, the starter is lighter in density than skim milk and tends to rise to the surface of the skim milk in the vat. The slight caramel color of curd containing the whole milk starter is sometimes objectionable.

## MAKING SWEET-CURD COTTAGE CHEESE WITH RENNET

In this presentation of the steps of manufacture we propose to indicate the variations to be followed when the long- and short-setting procedures of making are used. The essential differences in these procedures are in the temperatures of setting, and amounts of starter used.

## SETTING FOR THE SHORT PERIOD OF COAGULATION

**Temperature of setting.** When the short-setting method is used, the temperature of the pasteurized skim milk in the vat is adjusted to 85° to 90°F. Best results can be obtained only when the temperature is kept relatively constant. Heating to adjust the temperature of the vat of milk during the interval between the addition of starter and visible signs of coagulation is an undesirable practice. It frequently causes uneven coagulation and excessive curd losses. When the temperature of the skim milk cannot be maintained by using covered, water-jacketed vats, then the room temperature should be raised enough to prevent cooling. Temperatures lower than 85°F. delay acid development while those higher than 90°F. tend to increase the possibility of undesirable fermentations.

**Amount of starter.** When the short-setting method is used, the amount of starter to add to the skim milk is 4 to 5 per cent. With this amount of starter, cutting occurs in approximately 5 hours. This is usually the maximum amount of starter that can be used without decreasing the firmness of the Cottage cheese curd. Casein in starter is denatured by the high temperature of sterilizing. The soft gel, which is formed by the acid coagulation of casein in starter, is broken and dispersed in adding it to skim milk for Cottage cheese. Amounts of starter in excess of 5 per cent of the skim milk distinctly reduce the strength of the Cottage cheese curd during the cutting and subsequent making operations. This is sometimes a serious fault at times of the year when the skim milk itself tends to form a soft curd.

Starter is strained before it is added to the skim milk for Cottage cheese. This removes particles of curd and aids in thorough distribution.

### Setting for the Long Period of Coagulation

**Temperature of setting.** When the long-setting method is used for making Cottage cheese, the temperature of the skim milk is adjusted to 70° to 72° F. This temperature is easily maintained in commercial operations because it is so close to normal room temperatures. This temperature is most favorable for the development of the high, pleasing aroma that is characteristic of starter of high quality.

**Amount of starter.** When the long-setting process is used, the amount of starter to add to the skim milk is 0.3 to 1.0 per cent of the weight of the skim milk. The amount of starter is determined by the time when the desired acidity for cutting is to be attained in the skim milk. This is important because the long-setting period is most commonly an overnight setting period, and the maker is not there to begin the making operation if the acidity develops to the desired level too soon. In this respect the long-setting operation is not as well controlled as the short-setting procedure.

### Operations Followed in Both Short and Long Setting Methods

**Addition of rennet.** Rennet is added at the rate of 1 ml. for 1000 pounds of milk. Fractions of a milliliter are measured by diluting 1 ml. to 100 ml. with water. The necessary fraction can then be accurately measured since 1 ml. of the solution contains 0.01 ml. of rennet. For example, 10 ml. of this 1 to 100 solution contains enough rennet for 100 pounds of milk.

Rennet is diluted in at least 40 times its own volume of water just before it is added to the skim milk. This dilution assists in distributing the rennet uniformly throughout the vat of milk.

Rennet is added just before or just after the starter is added to the milk. After they have been thoroughly mixed with the skim milk, the vat is covered until the acidity and curd formation approach the desired optimum.

Coagulators, so called, are sometimes used in place of rennet. These preparations are dilute solutions of a coagulating enzyme, usually rennin or pepsin, or both. They may also contain added color and flavor which are harmless and unnecessary in the making of the cheese. These preparations for Cottage cheese are much more expensive to use than rennet. The manufacturers of such products state that these coagulators produce better cheese. No conclusive experimental evidence is available to show whether these claims are entirely justified.

**Effect of variations in amount of rennet.** Thurston and Gould (1933) varied the amount of rennet and the acidity of the curd at cutting and discovered that the best results were obtained when coagulation occurred not very much sooner than the right acidity for cutting. When rennet coagulation occurred too soon following the use of 1.5 ml. of rennet, or more, in 1000 pounds of milk then high acidity in the whey at cutting was associated with shattering of the curd during the early stages of cooking. Excessive amounts of rennet and very high acidity at cutting produced curd with no cohesive properties; such curd disintegrated into a small-grained product. These authors concluded that the coagulating function of rennet was secondary in importance to its action of preventing the matting of the flakes of curd during the heating operations. They recommended that the amount of rennet should be slightly less than that which causes disintegration of the curd during the curd making operations.

**Use of calcium chloride.** Federal definitions and those of some states permit the addition of a small amount of food-grade calcium chloride to the skim milk to be made into Cottage cheese. The amount of anhydrous calcium chloride is usually limited to 0.02% of the weight of the skim milk. The purpose of adding the salt is to improve the coagulating properties of the skim milk and to aid in the firming of the curd during heating.

Authorities do not agree on the necessity of using calcium chloride. Thurston and Gould (1933) observed no effects when they used it. They explained this by suggesting that coagulation by rennet is not desirable before the acidity reaches the level desired for cutting. Tracy and Ruehe (1936) recommended its use. Phillips (1944) indicated the purpose of using it was to remedy calcium deficiencies in the milk. Manufacturers in various sections of the United States have stated that they are using calcium chloride advantageously.

When a calcium deficiency in the milk supply is suspected, the use of the legal amount of calcium chloride is recommended. We have observed no instance when the addition of this salt was required for a normal milk supply of good quality. We have found it beneficial to use calcium chloride when excessive heat treatment in pasteurizing the skim milk tended to interfere with the normal functioning of rennet.

**Use of color.** A small amount of color, approximately 1 to 2 ml. for 1000 pounds of milk is sometimes used. Federal definitions do not permit it in cheese to be shipped in interstate commerce.

**Determining the time of cutting.** The cutting time and the condition of the curd at cutting is controlled by the amounts of rennet and starter used and by the temperature of the milk during the setting period. Adjustments are made in these factors when necessary so that the curd-making operations will conform to the most desirable routine of plant operations.

The exact time of cutting the curd is determined by measuring the titratable acidity of the whey or the pH of the curd. The most desirable titratable acidity of the whey at cutting approximates 0.5 per cent. The optimum pH of the curd approximates 4.6 to 4.7.

The whey for making this important titration before cutting must come from the interior of the curd. The whey must be clear and free of curd particles. It is obtained by centrifuging a portion of the curd in a Babcock cream test bottle. The curd to be centrifuged is drawn from beneath the surface of the coagulated skim milk with a pipette. Enough curd sample is taken to fill the cream test bottle to the base of the neck. The bottle of curd is then centrifuged at the usual speed of a Babcock tester for a period of about 3 minutes, or until the curd settles firmly in the bottom of the test bottle. The clear, supernatant whey can be decanted or can be removed with a pipette for titration.

The whey which sometimes appears over the surface of the curd at the expected time of cutting usually has a lower acidity than the whey which can be separated directly from the curd by centrifuging. If the operator depends on measurements of acidity in the whey which gathers over the curd, he may delay his cutting operations unduly. Under such circumstances the curd may be consistently higher in acidity than is desirable for optimum quality and yield.

**Effect of low and high acidity at cutting.** When the acidity at the time of cutting is too low, the curd develops a rubbery consistency. This defect is particularly apt to occur when the strength of the curd, rather than its acidity, is used to determine the time of cutting.

When the acidity of the curd at the time of cutting is too high, the curd tends to shatter in the making operations. Some of the curd tends to disintegrate to form curd dust which is lost with the whey. Excessive acidity is a common cause of low yield.

The limits of minimum and maximum acidity at cutting vary with milk composition, the heat treatment of the milk, and the combination of rennet action and acid development. Thurston and Gould (1933) worked with an unusual combination of these factors and reported good curd when the acidity of the whey at cutting was as low as 0.45 per cent. Lochry (1948) suggested a minimum acidity in the whey of 0.51 per cent and a maximum of 0.53 per cent.

**Size of curd knives.** The curd is cut with vertical and horizontal, wire, curd knives. The space between the wires ranges from one-quarter inch in some knives to as large as one inch in the larger knives. Knives used very commonly reduce the curd to three-quarter inch squares which are five-eighths of an inch thick. These large flakes are very popular in some of the most critical markets. Smaller cubes can be firmed more quickly and washed more efficiently to remove free whey and acid.

**Method of cutting.** The curd is cut first with the horizontal knife. This forms strips of curd extending the length of the vat. The vertical knife is then used to cut these strips first lengthwise and then crosswise of the vat. The handling of the knives is diagrammed in figures 12:3 and 12:4.

The curd is firm and has enough rigidity so that it maintains its position in the vat during the cutting operations. Overlapping of the paths of cutting and careless handling of the knives at the ends of the vat are important causes of excessive curd breakage.

**Heating the curd.** Heating of the normal curd begins immediately after cutting and continues for 1 to 2 hours until the temperature approximates 115° F. or until the curd becomes firm enough to remove the whey. If the curd is soft at cutting the heating may be delayed for 15 minutes or even longer.

Warm water in the jacket of the vat is used for heating the curd. The water is heated to temperatures of 15° to 25°F. higher than that of the curd and this differential is maintained as long as the speed of heating is satisfactory or until near the end of the heating process.

The early stages of heating can be simplified by gently running three or four inches of warm water over the top of the curd immediately after cutting. The temperature of this water should be 100° to 115°F. If there is room in the vat for only a very small amount of water, then temperatures of 120° to 125°F. may be used. Excessively hot water may cause the curd to mat. The addition of warm water warms the curd, reduces the acidity, and provides more free space for the movement of the cubes of curd. The treatment is highly recommended except when the acidity of the curd and whey at the time of cutting is in the minimum zone. Reduction of the acidity of such curd by the addition of water causes the curd to become slippery to the touch and to disintegrate. When the Cottage cheese must be made in a steam-jacketed vat, the addition of water to the curd in the vat is essential for the proper heating of the curd with minimum matting and breakage.

Stirring during the heating process is kept at a minimum. It is impossible to maintain an even temperature throughout the mass of curd until the last stages of heating. The first stirring need not begin until the warm water in the jacket of the vat causes the curd to shrink away from the metal.

Stirring is done first by hand scoops, flat paddles, or curd agitators made particularly for Cottage cheese by some equipment manufacturers. Rakes break the curd if they are used in the early stages of stirring; some operators refuse to use them at any time. The stirring at first is intermittent. It is done very gently. The scoop or paddle is inserted between the warmed curd and the side of the vat. The curd is then moved up and outward toward the center but it is not lifted out of the whey. The operation is repeated until warm curd has been gently rolled from all sides and ends of the vat into the top center part. This operation is repeated intermittently only as often as the curd can be moved without breakage. Occasionally the curd paddle is moved slowly beneath the curd to lift it from the warm bottom of the vat. Rate of agitation is gradually increased as the curd gains in strength and firmness.

The temperature is increased slowly at first. The final temperature of 110° to 120°F. is attained in 90 to 120 minutes when the large cubes of curd are handled. Smaller cubes can be heated in 60 minutes. Speed of heating is so adjusted that the gentle stirring necessary to prevent breakage of the curd is still adequate to prevent the formation of unwieldy masses of matted curd. The rate of heating may be increased when enough agitation can be applied to distribute the heat without breaking the curd particles.

Mechanical agitators can be used in the stirring of Cottage cheese curd during all except the early stages of heating. Such machines are still in the development stage for this special work, but agitators with slow speeds and modified paddles are now available to perform this difficult, tedious, and time consuming work.

The rate at which firmness develops depends on speed of heating and acidity of the whey at cutting as well as upon the size of the curd particles and conditions of heating. Large flakes of curd must be heated slowly or they will still be soft and mushy on the interior when the curd should be ready to remove from the whey. Firming progresses while the temperature is being raised; it becomes very slow when the flakes of curd attain the temperature of the whey. Slow, uniform application of heat produces the best firming effects.

Curd that is excessively acid at the time of cutting is difficult to firm. This condition is exaggerated if more than the required amount of rennet is used in making. Heating to high temperatures produces a shattering effect under these conditions. When it is necessary to firm such curd, it can usually be accomplished best by removing the acid whey from the vat until the curd is about to be exposed. This whey is then replaced with water at the same temperature. The heating is continued in the normal manner until the desired firmness is attained. This replacement of whey with water is undertaken as soon as it becomes apparent that the usual procedure will not be adequate to firm the curd. The treatment can be repeated if the curd is still excessively acid.

There is considerable disagreement concerning the maximum temperature for heating Cottage cheese curd. Temperatures of 110° to 120°F. in general seem to be effective for normal curd. Thurston and Gould (1933) suggested limits of 120° to 140°F. Phillips (1944) recommended 115° to 130°F. for manufacturers in California where the manufacture of the sweet-curd Cottage cheese is highly developed. Lochry (1948) mentioned final heating temperatures of 110° to 120°F. providing the acidity of the curd was normal at cutting.

The final objective of the heating operation is the development of the firmness desired for removing the whey.

**Removing the whey.** The whey is usually removed from the curd approximately 2 hours after cutting; the firmness of the curd determines the interval. Suitable allowance is made for the time consumed in draining the whey from the vat. Removal of whey from large vats is started earlier than from smaller vats.

The firmness of the curd at dipping is ideal when the particles have no soft centers, when a handful squeezed gently shows a slight elasticity, and when curd particles thoroughly chilled in cold water have the meatiness of ripe, pitted cherries. At this time the size of the curd particles approximates two-thirds of their original volume. The best judgment concerning these characteristics can only be exercised when practical experience in determining these properties has been checked by observations of the meatiness, size of particles, moisture content, and creaming properties of the finished cheese.

The operation of removing the whey begins by allowing the curd to settle to the bottom of the vat and then pushing it slowly away from the gate end for a distance of at least two feet. A vat strainer is inserted in the outlet of the vat, the uncut curd in the gate is removed, a strainer pail is hung on the gate, and the flow of whey is started. At no time should the rate of drawing the whey from the vat be fast enough to pull the curd around the vat strainer and so block the openings. When this happens the removal of whey becomes an unnecessarily laborious procedure.

When the curd begins to show above the surface of the whey it is time to begin making a trench to hasten the removal of the whey. A scoop with a strainer bottom is used to lift about one inch of the curd from the top and center of the mass in the vat. The curd removed is placed at the side of the vat. This removal is continued until this shallow trench extends from the gate end to the high end of the vat. It is usually necessary at this time to reduce the flow of whey from the gate so that the curd will continue to settle. The whey flows out of the vat over the top of the curd. The trenching operation is repeated as often as necessary to keep the whey flowing until the bottom of the trench is free of curd.

If the curd at this time has the desired body, it can be washed. If the curd is still slightly soft, the water should be withheld until the warm curd loses enough whey to reach the desired firmness. The curd changes very rapidly during this holding period. This is one of the most effective methods of firming soft curd.

The curd is not stirred during the interval of removing the whey excepting as it is necessary to form the trench down the center of the vat.

**Washing the curd.** The curd is washed after all of the whey has been removed. This treatment makes the curd firm and hard to the touch but it does not decrease the moisture content. Washing removes acid whey and aids in producing the desired mildness of flavor.

Water is applied, as a rule, in at least two treatments. The first, at a temperature of about 70°F., cools the curd and removes most of the sour whey adhering to the curd particles. The amount of water for washing should be not less than twice the volume of the curd in the vat. While the water is being added the gate is kept closed. After all the water has been applied the curd is turned over gently with a scoop so that every particle is exposed to the washing action. The washed curd is easier to handle without breaking than the warm curd but it is still fragile and care in manipulating it at this time helps preserve the large flakes of curd. After 15 minutes or more of soaking in the wash water, the curd is trenched beneath the water by gently pushing it towards the sides of the vat. The gate strainer is again inserted and the wash water is quickly drained off.

In the same manner the second and, if desirable, a third wash water are applied and removed. Water at 60°F. or lower is used for these last treatments; ice water is used by some manufacturers. Low temperatures are desirable to check fermentations and to chill the curd quickly before it is placed under refrigeration.

**Draining.** After the last wash water has been removed, the vat of curd is covered and allowed to drain thoroughly before it is ready for the next treatment. Any water trapped in the curd at this time is partially absorbed by the curd. Complete elimination of the free water produces a cheese that is drier and more desirable for creaming. A period not less than one hour is usually required to eliminate most of the free water entrapped by the curd. A longer draining period is necessary when the vat is worked at maximum capacity.

Draining of the curd is sometimes hastened by placing it in a draining rack with perforated bottom. These racks can be wheeled into rooms under refrigeration where they require no further attention until salting and creaming.

**Salting.** Salt is withheld until the free moisture has been drained from the curd. Earlier application of salt produces soft curd which leaks moisture when it is held or shipped in cans.

Salt can be applied to the curd in the vat or it can be dissolved in the cream to be used in the making of creamed Cottage cheese. Salt is applied in the vat by spreading it over the curd in two applications. The curd is turned over carefully after each application; the curd is easily broken at this time. Coarse salt is preferred because it dissolves more slowly.

The amount of salt added should not exceed 1 per cent of the weight of the curd. For some trade outlets, particularly the baking industry, salt may be omitted entirely.

**Refrigeration.** The salted or unsalted curd is held at 35°F. The curd is placed in straight-sided cans known in the industry as **cheese cans.** The cheese is shipped to distant points in these cans or in tinned cream cans, or it is packed and shipped in clean paraffined butter tubs lined with previously sterilized parchment paper. These containers are suitable for holding the curd during shipment from country plants to city markets for creaming and packaging. The tinned cream cans and butter tubs are preferred when the curd is held under refrigeration; paraffined cartons may be used for short distance transportation and quick merchandising.

**Creaming Cottage cheese.** Cottage cheese is creamed immediately after draining if the product is to be packaged at once. Many manufacturers prefer to hold the curd in a cold room overnight before creaming so that it will be more firm at creaming. If the cheese is to be shipped to a distant market the cream is mixed with the curd after delivery and before it is packaged for distribution to the consumer.

The amount of fat in the mixture of creamed Cottage cheese is prescribed by regulations in some localities and states. Shipments in interstate commerce must meet Federal standards. Usually, 4 per cent fat is the minimum permitted; 6 per cent is the maximum commonly used in commercial practice.

The fat content of the mixture of cream and milk added to the curd depends upon the firmness of the curd, the size of particles, the fat content desired in the finished cheese, and the preference of the consumers. Richer mixtures of milk and cream are used when the curd does not tend to absorb the cream, when the curd is in larger particles, when more fat is desired in the finished cheese, and when the consumer prefers a product with less free liquid around the particles of cheese.

Kelly and Price (1933) found that homogenizing cream before mixing it with the curd prevented separation of whey in the package. Homogenized cream mixtures that contained 20 per cent or more of fat showed a decided tendency to form thick glossy coatings over the curd particles; such mixtures exhibited little or no separation of liquid in the package of creamed cheese. The liquid which separated in the package, when homogenized cream was used to excess, was creamy rather than whey-like.

Cream is mixed with Cottage cheese curd in the vat or in a mechanical mixer. The first method is very commonly used; the second is followed in plants where large quantities of cheese are handled. Where mixers are used there is some breakage of the curd. Loehry (1944) stated that vigorous agitation in the mechanical mixer is necessary to produce the thick viscous mixture that is desired in certain markets. In other markets, the large flakes bathed in viscous cream are more highly praised than those mixtures which lack these large particles. The careful manufacturer must study the requirements of his market before deciding upon the technique to be used in mixing the curd with the cream.

Mixing is reduced to a minimum by some manufacturers who place half of the necessary amount of cream in the can in which the cheese is to be stored. The curd is added to the cream and the balance of the cream is then poured over the curd. The cans of cream and curd are held at 35°F. for approximately 16 hours during which time the cream is partially absorbed by the curd. The cans of creamed curd are emptied into the package fillers without any further agitation or mixing.

**Yield.** The yield of curd before creaming depends essentially upon the composition of the milk, the manufacturing losses, and the moisture content of the cheese. One hundred pounds of skim milk containing 8.5 per cent solids-not-fat commonly yields from 13 to 14.5 pounds of curd when it is made with rennet. When the curd is made without rennet, the yield from identical skim milk is usually slightly less. Some manufacturers have reported making 18 pounds of rennet-type cheese from 100 pounds of skim milk without exceeding the limit of 80 per cent moisture. This is theoretically possible when the skim milk contains 8.6 per cent or more of solids-not-fat.

The yield of creamed Cottage cheese represents a material increase in weight over the weight of the uncreamed curd. This

TABLE 24:2. AMOUNT OF CURD * AND CREAM IN 100 POUNDS OF CREAMED COTTAGE CHEESE

| *Fat in creamed Cottage cheese* | *When cream with 15% fat is used:* | | | *When cream with 20% fat is used:* | | |
|---|---|---|---|---|---|---|
| | *Curd* | *Cream* | *Creamed Cottage cheese* | *Curd* | *Cream* | *Creamed Cottage cheese* |
| % | lb. | lb. | lb. | lb. | lb. | lb. |
| 4 | 75.8 | 24.2 | 100 | 82.0 | 18.0 | 100 |
| 5 | 69.0 | 31.0 | 100 | 76.9 | 23.1 | 100 |
| 6 | 62.1 | 37.9 | 100 | 71.8 | 28.2 | 100 |

* It is assumed in these combinations that the curd contains 0.5% fat.

is illustrated in table 24:2 which shows the pounds of curd and cream in 100 pounds of creamed Cottage cheese. Other combinations can be calculated by using the Pearson's square method of standardizing which was described in Chapter 4. The combinations of cream and curd illustrated in this table are not intended to indicate ideal mixtures. Creamed Cottage cheese containing 6 per cent of fat contains too much liquid for most markets when it is made by mixing the curd with 15 per cent cream. The mixture containing 4 per cent fat made with 20 per cent cream, on the other hand, may be much too dry to suit other markets. The ideal combinations of curd and cream must be determined by the preferences of the customers.

The dry matter content of mixtures of cream and milk commonly used for creaming Cottage cheese approximate 20 per cent or more. Such combinations when added to the curd do not increase its moisture content beyond the 80 per cent limit of most regulations; the addition of high testing cream actually produces creamed Cottage cheese with less moisture than the curd from which it was made.

## MAKING COTTAGE CHEESE WITHOUT RENNET

The characteristic flavor of this kind of Cottage cheese is mildly acid. In appearance it is granular and sometimes flaky. In the aggregate it may suggest the appearance of popped corn. The consistency is firm and meaty, yet it is tender. Manufacturers who have difficulty in producing a desirable product with rennet frequently resort to this form of curd which is produced by the development of acid by lactic starter.

The discussions in this chapter on milk and starter for Cottage cheese also apply to this product made without rennet. The holder method of pasteurization is preferred over high temperature treatments for the sake of the slightly better curd formation.

**Temperature of setting.** For the short-setting process, temperatures of 85° to 90°F. are used. For the long-setting process the temperature of the milk is adjusted to 70° to 72°F.

**Amount of starter.** For the short-setting process 5 per cent of starter is used. For the long-setting process 0.3 to 1.0 per cent of starter is adequate; the exact amount is determined by the activity of the starter and the time when the curd is to be cut.

**Time of cutting.** The curd is firm enough and ready to cut when a knife drawn through it leaves a clean cut line in the curd. No acid determinations are necessary to determine the time of cutting. If the time required for the milk to coagulate is not known, then measuring acidity of the whey after cutting may be useful to indicate the desirability of making a change in the temperature of setting or the amount of starter. Long holding of the curd after coagulation and before cutting decreases the yield of this cheese.

**Size of knives.** Curd knives used are usually one-quarter inch or three-eighths of an inch in size. This size simplifies the heating operation by reducing the time required for heating. Curd particles of this size can be stirred more easily without breakage than larger ones.

**Method of cutting.** The curd is cut with both horizontal and vertical knives to produce cubes of uniform size and shape.

The acid coagulum is soft, fragile and easily disintegrated. A cube of the curd cannot be lifted out of the vat at the time of cutting. This is a marked contrast to the firmness of rennet-type curd. Every precaution must be taken to avoid unnecessary agitation of this curd.

**Heating of the curd.** It is wise to allow this curd to rest quietly in the vat for 15 minutes or more after cutting before beginning the heating operation.

The heating of this type of cheese follows the same general procedures described for heating rennet-type curd. The direct addition of warm water to the curd is recommended if the titratable acidity of the whey after cutting is over 0.55 per cent. The temperature of the warm water is best at 100° to 110°F.

Stirring is kept at the minimum necessary to prevent the formation of large, tough clumps or masses of curd. Some clumps will always form in the handling of this type of curd. The experienced operator knows how far this clumping can go without injuring the quality and appearance of the finished cheese. Stirring of the curd must be vigorous enough to prevent such injury. In the initial stages of heating this type of curd clumps more and breaks more easily than the rennet type of curd. That is one reason for the preferred use of the smaller knives for this acid-type curd; they minimize breakage. The first stirring of the curd after cutting follows the same routine described for rennet-type curd.

The maximum temperature for firming this curd ranges from 105° to 120°F., depending upon the size of particles and the firmness desired in the finished product. In general, the desired firmness is attained more quickly and at lower temperatures than for a comparable rennet-type curd.

Removing the whey, washing and draining of the curd, salting, and creaming of the cheese, follow the same general procedures described earlier in this chapter for rennet-type Cottage cheese.

**Composition.** Legal requirements commonly specify not more than 80 per cent moisture in Cottage cheese, and not less than 4 per cent fat nor more than 80 per cent moisture in creamed Cottage cheese. Such regulations do not apply in all localities.

Foter, Anderson and Dowd (1941) reported on the composition of more than 100 samples of Cottage cheese obtained from plants and in the open market. Fat ranged from 0.88% to 10.8% and averaged 3.64%. Moisture content ranged from 67% to 84.5% and averaged 69.62%. Salt content varied from 0.06% to 1% and averaged 0.5%. It is possible that the relatively low moisture content reported in these samples reflects the general trend of consumer preferences in the New England area where the samples were collected.

Garrett (1943) reported an average of 77.2% moisture in 102 samples obtained from 11 dairies in northeastern United States. The lowest moisture content observed was 71.29% and the highest, 85.11%. He found a calcium content of 0.08%, and a phosphorus content of 0.23%. He concluded, after comparing it with analyses of other human foods, that Cottage cheese is a good source of calcium and phosphorus in the human diet.

Phillips (1914) reported a range of 74.01 to 81.64% moisture in 16 samples of creamed and uncreamed California Cottage cheese. Two samples were below 75% and two above 80% moisture.

**Storage.** It is sometimes desirable to hold surplus Cottage cheese for later use. Ellenberger (1919) found that it could be kept in frozen storage for 4 or 5 months. He observed some defects in flavor and body in the defrosted product but concluded that the curd was preserved without spoilage so far as food value was concerned. Marquardt (1945) suggested that a satisfactory treatment for Cottage cheese was to freeze curd in 48 hours in 50-pound tins at 0° to —20°F. in an air blast. Defrosting in water at 70°F. required 2 to 4 days. The curd was then salted and creamed. He commented that the particles were reduced in size by the treatment.

Calbert and Price (1947) hastened the freezing of Cottage cheese by several different procedures such as using an air blast over thin layers of cheese; establishing direct contact between thin layers of cheese and low-temperature metal surfaces; bathing the curd in thin layers in freezing solutions made with alcohol and dry ice. Regardless of the speed of the freezing, no method was found which would prevent the development of the soft, pasty, mealy consistency after defrosting.

Cottage cheese held in frozen storage can be used without prejudice only if it is mixed in small amounts with fresh cheese.

Jensen (1942) found that Cottage cheese could be preserved in 3 to 4 per cent sodium chloride solution for 14 days at 45°F. Fouts and Mull (1943) reported that Cottage cheese without cream could be stored for 2 or 3 months at 30° to 40°F. by covering it with sodium chloride brine containing 4 per cent salt. Replacing the brine with fresh solution occasionally, maintained more desirable flavor in the cheese. The preserving brine covered the curd and limited the action of yeasts and molds. Such cheese was too salty for some users and so was washed with fresh cold water to remove the excess salt before creaming. Stanley (1918) approved the use of brine for preserving dry curd in transit. He pointed out that it maintained the freshness of the curd and prevented breakage.

## USE OF DRY SKIM MILK FOR COTTAGE CHEESE

During certain seasons of the year city markets are unable to obtain enough skim milk to supply their needs for Cottage cheese. In some areas of the United States the supply of whole milk is too limited for use for manufacturing purposes. It is possible to supply some of these needs by importing Cottage cheese manufactured in remote areas where skim milk is available. Skim milk in the dry form is also being used to a limited extent to satisfy these needs. Some dry milk manufacturers are making a special product for use in manufacturing Cottage cheese.

Reid and Fleshman (1932) recommended the use of high quality dry skim milk made by the spray or vacuum drum processes. They suggested mixing 3 to 5 pounds of dry skim milk with 100 pounds of fluid skim milk at 90°F., or the mixing of 12.5 pounds of dry skim milk with 87.5 pounds of water at the same temperature. They mixed the combinations thoroughly and then strained them. They added starter at the rate of 5 per cent, rennet at the rate of 2 milliliters per 1000 pounds of mixture, and a small amount of calcium chloride. Their setting temperature was 86°F. Coagulation occurred after 5 hours and the curd was cut at a "clean break" when the acidity in the whey was 0.45 to 0.55% for the skim milk containing 3% added dry skim milk, 0.5 to 0.6% for skim milk with 5% added dry skim milk, and 0.35 to 0.45% in the whey from the water and dry skim milk mixture.

These authors recommended the use of one-half inch knives. They allowed the curd to set for 30 minutes after cutting. They added 2 inches of hot water at 130° to 140°F. to the vat, and 10 minutes later, more water at 150° to 170°F. The final heating temperature attained was 120° to 130°F. They removed most of the whey when the desired firmness was reached and added wash water when the receding whey exposed the curd. They suggested that the curd be stored in ice water until ready for salting and creaming.

Reid and Maughan (1947) experimented further with the use of nonfat dry milk solids. They suggested making a 20% mixture of these solids in water at 90°F. They added starter at the rate of 12% and obtained coagulation in about 3 hours. They cut the curd at a "clean break" with an acidity in the whey of 0.6 to 0.9%. After cutting the curd in the normal manner they allowed it to stand for 60 minutes to "firm up."

These authors used liberal amounts of hot water to heat and agitate the curd. They added the water in 3 or 4 portions at temperatures increasing from 120° to a final temperature of 140°F. The amount of water added approximately doubled the volume of milk originally in the vat. At the same time they applied heat in the jacket of the vat. They limited stirring to 3 times in the first 60 minutes after the start of heating. The final temperature attained was 120°F. and the curd was held at that point until it became firm enough to drain.

Reid and Maughan removed whey and added cold water simultaneously until the acidity of the wash water was 0.02 to 0.06%. They stored the curd in cold water or in a 1.5% salt solution at 40°F.

Tretsven (1918) announced the development of Lacal, a new dehydrated milk product which provides cheese solids in a concentrated form for use in areas where fresh skim milk is not available. He stated that Lacal is superior to ordinary dried milk because it has better curd-forming properties, and better color, flavor, and yield.

## DEFECTS IN COTTAGE CHEESE

The defects in Cottage cheese can usually be traced to inferior raw milk, or cream, or both, or to lack of proper pasteurization, inferior starter, faulty or careless manufacturing procedures, insanitary conditions in pipelines, vats, utensils, manufacturing rooms, or storage rooms, holding at high temperatures, or delay in merchandising. The chief defects and their common causes will be mentioned under the general headings of flavor, body, and appearance.

## FLAVOR DEFECTS

**Sour flavor.** This flavor is caused by inferior milk, excessive acid development, retention of too much whey in the curd, lack of firming, lack of washing, or lack of draining.

**Yeasty or fermented flavors.** These flavors are somewhat alike and are caused by growth of yeasts, bacteria, or molds in or on the curd. Contamination with these organisms can usually be traced to inferior milk, cream, or starter, and to the use of non-sterilized equipment and utensils such as pipelines, vats, and containers used for storing the cheese. The defect is increased by lack of chilling before placing the cheese in the refrigerator, holding at temperatures above 40°F., and by holding the cheese too long before merchandising.

**Unclean flavors.** Such flavors are caused by inferior milk, cream, or starter, by unclean utensils, contaminated water supply, and unsanitary storage conditions.

**Feed flavors.** These are caused by the odors of feed in the original milk. They may be particularly objectionable in certain areas or at certain seasons of the year. These strong flavors may be in the feed fed in the barns or they may be in weeds or other strongly flavored feeds picked up by the cows in pastures.

## BODY DEFECTS

**Dry and hard.** This condition is caused by lack of moisture in the cheese. Insufficient moisture may be caused by small size of curd particles, overheating during firming, draining too long before washing with cool water, and by lack of cream in creamed Cottage cheese.

**Soft, sticky, pasty.** These characteristics are different degrees of the same defect and are caused by too much moisture in the curd. Excessive amounts of moisture can be attributed to the use of too much rennet followed by high acid development, development of too much acid, curd particles of large size, rapid heating, soft centers in the curd, insufficient firming of the curd, addition of cold wash water before all of the whey has been removed, lack of draining, and salting too soon after washing.

**Grainy or gritty.** The presence of many very small, gritty, hard particles is caused by a combination of those factors which hasten removal of moisture and make dry curd and by other factors which cause breakage of the curd. Rough handling of a normal curd during the heating operation causes gritty cheese.

**Rubbery or tough.** This condition is caused by cutting the rennet-type of curd before sufficient acid has been developed. There is no remedy for the condition after it has once appeared. The defect can be prevented by accurate titration of the whey which can be separated from the curd before cutting, and by measuring the pH of the curd itself before cutting. Acidity limits at cutting are discussed in this chapter in the description of making Cottage cheese with rennet.

## APPEARANCE DEFECTS

**Small particles.** This defect may be caused by any condition that induces breakage of the curd. It may be attributed directly to overlapping of knives in cutting, use of milk which was overheated in pasteurizing, breakage of curd during cooking through rough handling or overstirring, too much curd in the vat, and by excessive stirring or mixing during the operations of draining, salting, creaming, and during the filling of packages.

**Watery.** Too much free liquid in the package gives this appearance to the cheese. It is caused by too much cream, lack of draining before salting and creaming, lack of mixing of cream with curd, and hard, acid curd which lacks cream-absorbing capacity.

**Wheying off.** A clear, watery serum, which resembles whey, appears when there is too much cream, when the creamed cheese is held too long, when the cheese is stored at high temperatures, and when non-homogenized cream is used for creaming the curd.

## NUTRITIVE VALUE

Cottage cheese is an attractive item in the diet of the American people. Its approximate composition and food value are shown with those of Cream cheese and Cheddar cheese in table 24:3.

TABLE 24:3. PROXIMATE COMPOSITION AND NUTRITIVE VALUES OF ONE POUND OF EACH OF COTTAGE CHEESE WITHOUT CREAM, CREAM CHEESE, AND CHEDDAR CHEESE

(U. S. Dept. Agr., Misc. Publ. 572, 1945)

| *Constituent* | *Cottage cheese* | *Cream cheese* | *Cheddar cheese* |
|---|---|---|---|
| Protein, gms. | 87.2 | 32.2 | 108.5 |
| Fat, gms. | 3.6 | 167.5 | 146.6 |
| Carbohydrate, gms. | 19.5 | 7.7 | 7.7 |
| Calcium, mgs. | 372.0 | (1353) | 3963 |
| Phosphorus, mgs. | 1194.0 | (944) | 2769 |
| Iron, mgs. | 2.1 | (0.8) | (2.6) |
| Vitamin A, I.U. | (150.0) | 10050 | 7920 |
| Thiamine, mgs. | 0.08 | (0.06) | 0.20 |
| Riboflavin, mgs. | 1.32 | 0.65 | 2.29 |
| Niacin, mgs. | (0.5) | 0.30 | (0.9) |
| Ascorbic acid, mgs. | (0.0) | (0.0) | (0.0) |
| Food energy, calories | 459 | 1667 | 1784 |

Numbers in parentheses are imputed values.

## REFERENCES

Calbert, H. E. and Price, Walter V. (1947). Unpublished data. University of Wisconsin, Madison.

Ellenberger, H. B. (1919). Vt. Agr. Expt. Sta., Bul. 213.

Food and Drug Administration (1942). Fed. Reg., *7,* 10755.

Foter, M. J., Anderson, E. O., and Dowd, L. R. (1941). J. Dairy Sci., *24,* 544.

Fouts, E. L. and Mull, L. E. (1943). Fla. Agr. Expt. Sta., Bul. 382.

Garrett, O. F. (1943). J. Dairy Sci., *26,* 305.

Jensen, Chris. (1942). N. Dakota Agr. Expt. Sta., Bimonthly Bul. 4, No. 5, 19.

Kelly, Martin F. and Price, Walter V. (1933). Nat. Butter and Cheese J., *24,* No. 4:10. Feb. 25.

Lochry, H. R. (1948). U. S. Dept. Agr., Misc. Publ. 119, 1931. Revised, 1948.

Marquardt, J. C. (1945). Food Ind., *17,* No. 5:81.

Phillips, C. A. (1944). Cal. Agr. Ext. Service, Circ. 48, 1930. Revised, 1944.

Reid, W. H. E. and Fleshman, C. L. (1932). Amer. Creamery & Poultry Prod. Rev., *74,* 534. Aug. 10.

Reid, W. H. E. and Maughan, Merril O. (1947). Mo. Agr. Expt. Sta., Bul. 505.

Stanley, W. C. (1948). Milk Plant Mo., *38,* No. 3:52.

Thurston, L. M. and Gould, I., Jr. (1933). J. Dairy Sci., *16,* 467.

Tracy, P. H. and Ruehe, H. A. (1936). Ill. Agr. Expt. Sta., Cir. 445.

Tretsven, W. I. (1948). Milk Plant Mo., *37,* No. 3:38.

United States Department of Agriculture (1948). Production of manufactured dairy products, 1946. U. S. Dept. Agr., Bur. Agr. Econ., Washington, D. C., May, 1948.

United States Dept. of Agr. (1945). U. S. Dept. Agr., Misc. Publ. 572.

# CHAPTER 25

# CREAM AND NEUFCHATEL CHEESE

Cream cheese is a soft, unripened cheese made from cream, or from mixtures of cream with milk or skim milk. The Cream cheese most commonly made in this country is a relatively new product. It has been developed commercially since 1920. It has a rich, mildly acid flavor and a smooth, buttery consistency which permits slicing with a wire knife without breaking or crumbling. When it was first introduced it was known as Loaf Cream cheese because it was commonly merchandised in the form of 5-pound or 3-pound loaves. It was also known as **Low-acid,** or **Cooked-curd Cream cheese** to distinguish it from the traditional form of Cream cheese made by the Neufchatel process. The traditional form was more acid and was made from non-heated curd.

The definitions and standards of identity of the Food and Drug Administration (1942) broadened the meaning of the term **Neufchatel.** It still covers the product that is made from non-cooked curd by the traditional process. It also includes cheese made by the cooked-curd method. The definitions clearly indicate that Neufchatel cheese, regardless of the method of manufacture, is the same type of cheese as Cream cheese, but it must contain less fat and may contain more moisture than Cream cheese.

The traditional Neufchatel process, which was developed in France, was described by Matheson, Thom and Currie (1914) and Matheson and Cammack (1918). This process is used today in making Baker's cheese from skim milk and for making Neufchatel curd from whole milk.

The Food and Drug Administration (1942) published definitions for Cream and Neufchatel cheese. These definitions specify that Cream cheese should contain not less than 33 per cent fat nor more than 55 per cent moisture. Neufchatel cheese is described as containing not less than 20 per cent fat but less than 33 per cent and not more than 65 per cent moisture. The definitions permit the use of stabilizers and list gum karaya, gum tragacanth, carob bean gum, gelatin, or algin; they may be used alone or together providing their total solids content does not exceed 0.5 per cent of the weight of the cheese. The presence of these stabilizers must be indicated on the label of the package of cheese.

The dairy products which may be used in the making of Cream and Neufchatel cheese include cream, milk, skim milk, concentrated milk, concentrated skim milk, and nonfat dry milk solids. Federal regulations and the regulations of many states require pasteurization of the mixture of these products during the making of the cheese.

In this discussion we will describe the manufacture of Cream and Neufchatel cheese as they are now made commercially. We will then present the details of making some closely related products. Next we will explain the traditional Neufchatel process which is applied in the making of Baker's cheese and to a limited extent in the making of Neufchatel cheese from whole milk or enriched milk.

## MANUFACTURE OF CREAM CHEESE BY THE COOKED-CURD METHOD

The cooked-curd system of manufacturing Cream and Neufchatel cheese is preferred because it produces ideal flavor and body and still permits a high yield. Fisk (1925) first described the essential operations. Marquardt (1927), Reichart (1936), Roundy (1939), Roundy and Price (1941), and Zakariasen and Combs (1941) by their experimental work have contributed to a better understanding of some of the factors influencing the quality of the product. Dahlberg (1927), Dahlberg and Marquardt (1934) and Reichart and Crowe (1941) have introduced some novel methods of making products which have properties like those of Cream cheese. These products do not conform, strictly speaking, to the definitions of Cream cheese of the Food and Drug Administration.

### Preparation of the Mix

The mix consists of the cream or the mixture of cream with milk or skim milk or both.

**Ingredients.** Fresh milk products of high quality produce Cream cheese of superior quality. Cream cheese has limited keeping properties. It is common practice, during seasons of limited supplies, to use frozen cream. Concentrates of milk or skim milk may be used in cheese to be shipped in interstate commerce. Concentrates of skim milk or milk have been used successfully for making products similar to Cream cheese (Dahlberg, 1927; Dahlberg and Marquardt, 1934; Reichart and Crowe, 1941).

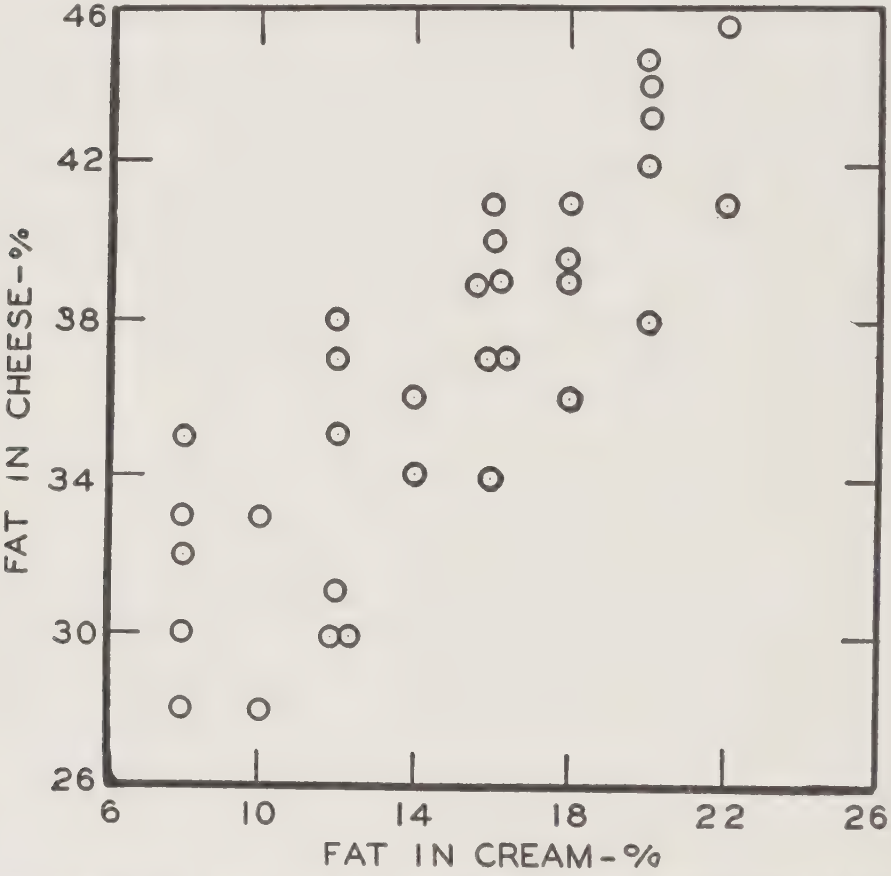


Figure 25:1. The fat content of the cheese increases as the percentage of fat in the cream increases. (*Roundy and Price, 1941*).

**Fat in the mix.** The fat content of the mix has a marked influence on the quality, composition, and yield of Cream cheese. Roundy and Price (1941) studied these effects. They used mixes containing as little as 8 per cent fat and as much as 22 per cent and reported the best flavor resulting from the use of mix containing from 16 to 20 per cent fat. Cheese from mix with less than 14 per cent fat tended to be dry, crumbly, mealy, and grainy. Increased moisture in the cheese improved only the dry, crumbly condition; too much moisture caused excessive leakage of the cheese in the package and injured the keeping quality of the cheese.

The fat and moisture in the finished cheese are directly affected by the composition of the mix, according to Roundy and Price (1941). The trends of these effects are shown in figures 25:1 and 25:2. Regardless of the composition of the original cream, the fat and moisture in the curd obtained from mix of any composition can be expected to vary widely. Mixes with 12 per cent fat represented in figures 25:1 and 25:2 made several lots of cheese with less than the minimum fat and more than maximum moisture permitted by the Federal standards for Cream cheese.

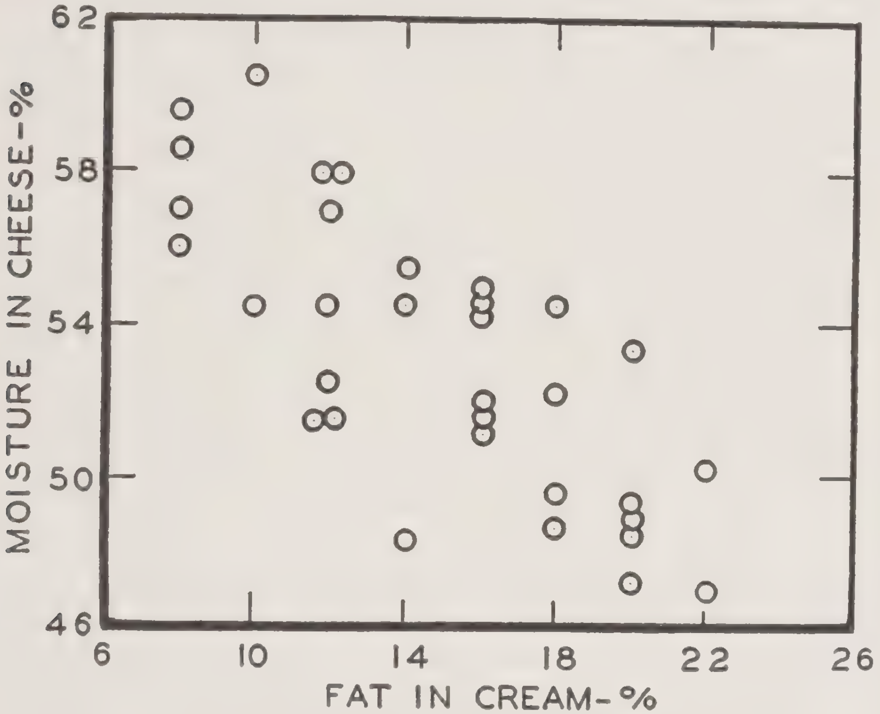


Figure 25:2. The moisture content of Cream cheese tends to decrease as the fat content of the cream increases. (*Roundy and Price, 1941*).

Uniformity of composition is attained in commercial practice by combining batches of different fat and moisture contents. A further opportunity for some adjustments are possible when the hot-pack method of manufacture is used. This method is discussed on page 418.

One of the most striking effects of variations in the fat content of Cream cheese mix is its relation to the rate of drainage.

Roundy and Price (1941) measured the amount of whey separated from 10 pounds of mix in the first 90 minutes of the draining period. Cream with 20 per cent fat lost only half as much whey in the 90 minute period as cream with 10 per cent fat. They regarded this difference as an important reason for the common industrial use of mixes with less than 16 per cent fat. The extent of the influence of fat on whey drainage is indicated in figure 25:3.

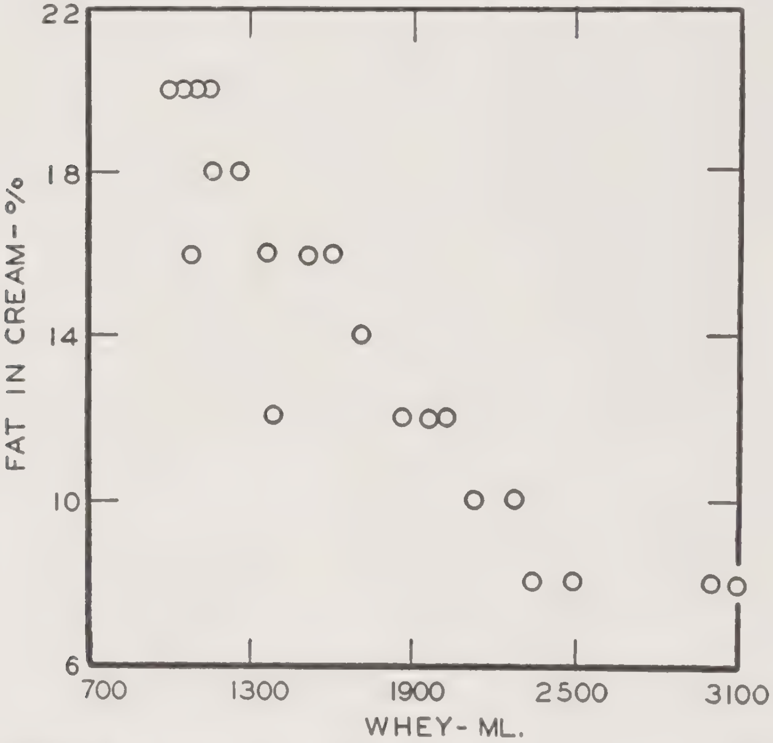


Figure 25:3. The amount of whey draining from the curd increases as the fat content of the cream decreases. (*Roundy and Price, 1941*).

**Pasteurization of the mix.** Pasteurization is essential in making this cheese. It improves the quality, keeping properties and uniformity of the finished product. It is a justified precaution for the protection of the public health and is usually required where regulations exist for the merchandising of the cheese.

Heat treatments recommended for the mix range from 145°F. for 30 minutes to 180 F. for the same time. Some of the earliest information (Fisk, 1925) and some of the most recent experimental work (Zakariasen and Combs, 1941) have indicated the beneficial application of temperatures in the maximum zone. Roundy (1939) preferred pasteurization at 145°F. for 30 minutes rather than 180°F. for 30 minutes. Lower temperatures of pasteurization give a faster draining curd and for that reason are generally preferred.

**Homogenization of the mix.** Temperatures and pressures of homogenizing have been varied over wide ranges in practical and experimental work. Early descriptions of the process (Fisk, 1925) commonly recommended 1800 pounds pressure at 145°F. Marquardt (1927) found that 2000 pounds pressure, or above, at 130°F. produced smooth cheese and minimized fat losses in the whey. Reichart (1936) preferred 2000 to 3000 pounds pressure at 145°F. Roundy (1939) advised temperatures between 110°F. and 130°F. and pressures of 1000 to 2000 pounds with a Manton-Gaulin homogenizer; under such conditions he observed the most favorable effects on flavor, consistency, fat losses, and draining rate. Zakariasen and Combs (1941) obtained their best results with 175°F. and 4000 pounds pressure.

Roundy and Price (1939) pasteurized at 145°F. for 30 minutes, cooled the mix to 120°F. and homogenized at 1500 pounds pressure in a Manton-Gaulin homogenizer. This treatment has been followed successfully for a number of years using either the Manton-Gaulin or Creamery Package homogenizers. Double stage homogenizing can be used but does not improve the quality of the cheese.

The successful results reported by these workers, who used a wide variety of conditions of manufacture, indicate that efficient homogenizing is probably the primary objective in making this type of cheese. Efficient homogenizing distributes the fat of the mix so that it is retained in the curd and not lost in the whey; it imparts smoothness to the cheese; and finally it makes possible the speedy separation of the whey from high-fat curd. Roundy (1939) explained these actions by pointing out that the homogenizing treatment probably destabilized the protein at the same time that it caused drastic adsorption of the protein on the surfaces of the fat globules. When these effects were carried to excess in the course of rigorous homogenizing treatments, he observed slight decreases in the rate of whey drainage and in the smoothness of the finished cheese. When, on the other hand, homogenizing was inefficient, he observed that the Cream cheese mixes did not drain within a reasonable length of time.

**Conditions of curd formation.** The formation of the curd is regulated to suit the time allotted for manufacturing and the period in the day when the work must be scheduled for greatest plant efficiency. Table 25:1 shows two suitable combinations—one for a short-setting period, the other for a long-setting period.

TABLE 25:1. CONDITIONS AND SPECIFICATIONS FOR CURD FORMATION

| *Conditions* | *Specifications* | |
|---|---|---|
| | *Short-setting* | *Long-setting* |
| Temperature of coagulation | 90°F. | 72°F. |
| Rennet for 1000 lb. mix | 1 ml. | 1 ml. |
| Starter for 1000 lb. mix | 50 lb. | 4 lb. |
| Time from setting to stirring | 5 hours | 15 hours |
| Acidity of curd at stirring | 0.6% | 0.6% |
| pH of curd at stirring | 4.7 | 4.7 |

**Temperature for curd formation.** The temperature of setting Cream cheese is usually 72°F. or 90°F. The lower temperature is used when the long-setting or overnight process fits best into the plant operations. The higher temperature is favored when a 5-hour setting period is preferred. The characteristics of the cheese produced by the two setting temperatures are practically identical.

**Rennet.** Use of rennet is desirable for the making of Cream cheese; without it, the curd retains its moisture for unreasonable periods of time. Only a small amount, approximately one milliliter for 1000 pounds of cream, is necessary to achieve the minimum curd effects desired. The addition of more is permissible but apparently unnecessary.

Marquardt (1927) used mixes with 5.46 per cent fat and used 1.5, 20, and 60 ml. of rennet for 1000 pounds of mix. The variations did not materially affect drainage although excessive amounts made dry, lumpy curd. Reichart (1936) observed that a 12 per cent fat mix with no rennet produced smoother cheese and less leakage than mix with 10 ml. of rennet per 1000 pounds. The curd made without rennet was slow to drain; usually it was sufficiently pressed 48 hours after it was placed in the bags for draining.

Roundy (1939) used from 0 to 28 ml. of rennet per 1000 pounds of mix and observed no differences in the quality of the finished cheese. Drainage of whey was retarded by omitting rennet entirely. Leakage of whey from packaged cheese was increased when large amounts of rennet were used. Roundy expected the curd to be sufficiently drained within a period of 4 hours after it was placed in the bags.

**Starter.** Lactic starter is used to produce the acid required for coagulation and for the development of the characteristic mild-acid flavor of Cream cheese. High quality and activity are required in the lactic starter used in this cheese.

The amount of starter is adjusted to attain the desired acid development in the correct period of setting. Slightly different amounts may be used under different conditions of manufacture to compensate for variations in strains of starter, temperature controls, and the like. Five per cent of starter is recommended for the short-setting period and approximately 0.4 per cent for the long-setting period.

Roundy (1939) varied starter from minimum amounts up to 25 per cent of the weight of the mix. Lots of cheese with 2.5, 5, and 10 per cent starter were practically the same in quality. The use of 10 and 25 per cent of starter delayed the drainage of whey. The cheese made with 25 per cent starter was definitely flavored with the sterilized milk odor of the starter; the body of the cheese was not injured. The acidity measurements of the finished cheese showed no relation to the amount of starter used.

**Changes in mix and curd during the setting period.** The changes which take place in the mix during the period of coagulation consist of the formation of a soft curd and the development of acid. The measurement of developed acidity is used to determine the end of the setting period which is the time for stirring the curd. The optimum titratable acidity of the mix to begin stirring approximates 0.6 to 0.8 per cent.

Reichart (1936) found that 0.6 to 0.7 per cent of acid gave the best results when no rennet was used. Development of higher acidities before agitation he associated with sour cheese, while lower acidities produced stringy, rubbery curd.

Roundy (1939) studied the influence of acidity at stirring. He used 3 ml. of rennet per 1000 pounds of 16 per cent fat mix and a setting temperature of 90°F. He found that this cheese was usually grainy, mealy, dry, and crumbly when the pH at stirring was less acid than 4.9. Such curd drained very fast and occasionally fat losses in the whey were excessive. He obtained best results when the acidity at cutting was 4.6 to 4.7 pH; the equivalent in titratable acidity approximated 0.6 per cent to 0.7 per cent.

Zakariasen and Combs (1941) secured a fine, mild flavor in Cream cheese made with 16 per cent fat mix when the titratable acidity of the mix developed to 0.7 to 0.8 per cent.

Measurements of titratable acidity in coagulated mix can be made most accurately by weighing 9 grams of cream into the titration flask or cup. Volumetric measurements with a pipette can be used for titration if care is taken to measure the correct amount of cream with the pipette and then to make certain that all of this cream is neutralized in the titration.

Allowances must be made for the fat content in Cream cheese mix when titratable acidity measurements are used to determine the end of the setting period. Mix with high fat content has a slightly lower titratable acidity than mix with a lower fat content. For example, the curd from a mix containing 20 per cent fat can be stirred and heated when the acidity is 0.58 per cent. A comparable acidity and curd condition in a 12 per cent mix is attained at 0.64 per cent.

**Stirring the curd.** When its acidity reaches the optimum point, the curd is stirred until all lumps have been broken and the consistency is smooth and homogeneous like that of rich, fresh cream.

The Cream cheese mix is usually held in vat pasteurizers during the period from setting to stirring. Such pasteurizers are ideal when they are made from stainless steel and so designed that they can be easily and completely cleaned and sterilized. It is important that the pasteurizer should be able to stir the coagulated mix to a smooth and homogeneous consistency and should be able to do so in a reasonable length of time. The pasteurizer should have sufficient capacity to hold the water that may be added to it during the heating operation or before draining. It should be so installed that the curd can be conveyed to the draining bags by gravity or pump with a minimum of hand labor. These general requirements can be met with different equipment in different plants. On the small scale, well-tinned cans or a stainless steel cheese vat can be made to serve the purpose of the pasteurizing vat.

**Heating the curd.** Two methods of heating the curd are used. In the first method the cream is stirred in the pasteurizing vat and slowly heated to a temperature of 115° to 125 F. in 45 to 60 minutes. It is held at this temperature until it is clear that whey is separating from the curd. Rivulets of whey that form in a few seconds on a spatula, which is immersed and then withdrawn from the hot mix, are indicative of whey separation. The curd is then ready to drain. It may or may not be cooled before it is placed in the draining bags. Reichart (1936) advocated the homogenizing of the cooked curd, made without rennet, at 300 to 500 pounds pressure before cooling it and placing it in bags; this treatment was very effective in hastening the drainage of the whey and in improving the texture of the cheese. Roundy (1939) found that homogenizing the curd caused more leakage of whey from the finished cheese when rennet was used in forming the curd.

In the second method of heating, water is added directly to the curd. In this treatment it is essential to have the curd in a pasteurizer or vat that is only half-full. The curd is first stirred until it is smooth and homogeneous. Hot water at 170° to 180° F. is then poured into the smooth mix while the mixture is stirred continuously and thoroughly. The curd is ready to drain as soon as the mixture reaches 120° to 130° F. This will require a volume of water approximately equal to the volume of the curd. The mixture of curd and water is then poured into the draining bags without cooling.

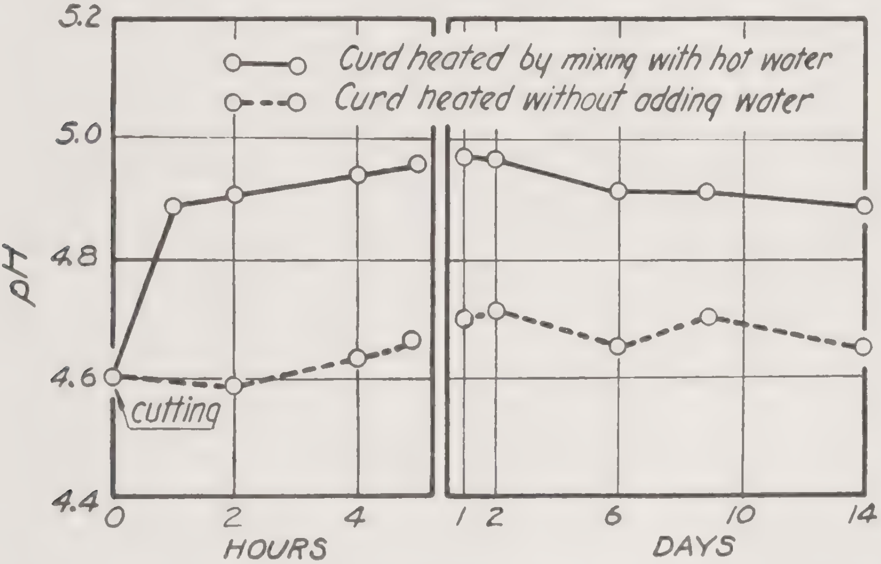


Figure 25:4. Mixing hot water with the curd before draining increases the pH of the curd and the cheese. This decrease in acidity is easily observed in the flavor of the Cream cheese. (*Roundy and Price, 1941*).

This method of heating with added water shortens the process of making and produces sweeter cheese, as shown in figure 25:4. More draining bags are used, but the duration of the draining period is shorter and the pressing operation is correspondingly decreased or even eliminated entirely (Roundy, 1939).

**Draining of the curd.** When the curd is ready to drain, it is placed in bags made of unbleached muslin sheeting. The cloth is a durable material woven loosely enough to permit the flow of whey but close enough in texture to retain the particles of curd. Suitable bags are formed by placing together the two diagonally opposite corners of a square piece of the muslin cloth. The square of cloth should be about 40 by 40 inches. One short side of the triangle so formed is then sewed together to form a pointed bag, triangular in shape, the open side of which is approximately 40 inches long.

The draining bags, when filled to within about 10 inches of the top, hold approximately 35 pounds. The bag is made ready for tying shut by grasping the "right angle" corner of the bag in the right hand, gathering the open edges of the mouth of the bag in the fingers until the bag and its contents can be lifted with the left hand without spilling. The loose corner of the top of the bag is then wound tightly around the top of the bag above the bulge formed by the curd and under the left hand. The tail end of the loose corner is merely tucked under the firmly twisted knot. The tied bags are lifted only by grasping the knot.

The whey flows freely from the bags at first. They require no pressing during this interval. They are placed in cheese vats or on draining racks and are spread out to expose as much surface as possible for drainage. Stainless steel or aluminum racks or perforated plates are placed over the bottom of the vat to assist in the rapid removal of the whey.

As the whey leaves the bags they flatten out. At this stage they can be shaken enough to loosen the partially drained curd from the cloth. When the bags are about half drained they are piled up in the vat to increase the pressure on them. Some operators pile and repile the bags of curd in the vat in this manner until sufficient whey has been removed. Other operators pile the half-drained bags in bins with alternate layers of chipped ice to complete the draining operation. Still other operators merely apply weights or pressure to the partially drained bags in order to remove the remainder of the free whey.

The end of the draining operation is attained when the moisture content of the curd has been reduced to the desired level. This is indicated approximately by measuring the gross weight of a number of the bags in the batch. A quick estimate of moisture can be made with a "drying" lamp. The sample of the curd for drying is obtained by mixing together small portions taken from several bags. The use of this lamp for moisture estimates is described in Chapter 28. The Mojonnier tester is ideal for this control purpose.

The curd at the end of draining varies in consistency with the temperature. The consistency is like that of ice cream as it is drawn from the freezer if the temperature approximates 70°F. It is a firm cake if it has been chilled. Actual analyses, rather than personal judgment, are essential for accurate control of the composition and quality of the curd.

This long and laborious process of removing the whey from the curd has been mechanized by Strezynski (1947) of the DeLaval Separator Company. The machine is a centrifuge. The heated mix passes continuously through the bowl of the centrifuge which is provided with two outlets. Whey is removed from one outlet while the concentrated curd is removed from the other. The mixture entering the bowl is maintained at a temperature of about 160 F. The machine is so designed that measured amounts of such additives as gum, salt, and flavoring ingredients may be continuously injected into and mixed with the Cream cheese as it is discharged from the machine. This development may have a profound effect on the general procedure for making Cream cheese.

**Cold-pack treatment of drained curd.** When the curd has been drained to the desired moisture content it is emptied from the bags into a suitable mixing vat. This offers the operator his last opportunity to standardize the composition of his product by properly blending low and high moisture bags or batches to obtain the desired moisture. Fat losses in the manufacture of Cream cheese are negligible. The inverse relationship between moisture and fat in the cheese is fairly close so that standardization of the fat content by blending also adjusts, with a fair degree of accuracy, the moisture content of the finished cheese. The adjustment, of course, must be verified by analysis. In good practice (Food and Drug Administration, 1942) the variations in the final package may be 2 per cent of fat or moisture above or below the desired composition.

Salt is mixed with the curd at the rate of 0.8 to 1.0 per cent of its weight. While the curd is still soft, as it will be if it has not been previously chilled, it can be packaged mechanically in glasses, packages, or suitably lined boxes. Tin-foil and aluminum-foil have been used successfully for box linings for many years. Manufacturers and processors of new types of moisture-proof, transparent, and semi-transparent films, such as Pliofilm and Cellophane, have made possible the development of some very effective modern packages for Cream cheese.

Some operators place the salted curd in forms for chilling. The curd has a firm consistency when the butter fat hardens for 15 hours at 35°F. In this state the curd can then be printed and wrapped in 3 to 6 ounce packages in which form it is often sold.

Pimiento, pineapple, pickle relish, chives or other flavor materials are sometimes added to Cream cheese at the end of the draining process and just before packaging. The amounts of such flavoring substances added to the curd may vary from 5 to 20 per cent of its weight according to the desire of the operator and the intensity of flavor and consistency of the added substance.

**Hot-pack treatment of drained curd.** In the hot-pack process it is the common practice to mix and heat a vegetable gum with the Cream cheese curd at the end of the draining period. The composition of the mixture is further adjusted by the addition of cream, milk, concentrated milk, skim milk, concentrated skim milk, or dried skim milk. Finally, the mixture is pasteurized, homogenized, and placed immediately, or as soon as possible, in the final package. Temperatures of heating and pressures of homogenizing are varied widely. The range approximates 120° to 175°F. while pressures range from 1000 to 3,500 pounds.

The gums most commonly used to prevent leakage of whey from the hot-pack cheese are carob or locust bean gum, karaya gum, and gum tragacanth. Gelatin and algin are also effective and are used sometimes. The amounts of gums or mixtures of them required for the desired effect do not exceed 0.5 per cent of the weight of the finished cheese. (Food and Drug Administration, 1942).

Roundy (1939) used fresh, pasteurized cream without gums to standardize drained curd to the fat content desired in the finished product. He heated the mixture to 145°F. and then homogenized it at 3500 to 4000 pounds pressure, single stage. The resulting product was very smooth and more uniform in fat and moisture content than the original batches of drained curd. Roundy's product sometimes leaked moisture in the final package. He prevented this defect by adding gelatin before heating and homogenizing. He commented that the standardized, homogenized cheese was inclined to be too soft in consistency when it was low in solids, and it was sticky when too much gelatin was used.

Zakariasen and Combs (1941) experimented with mix containing 16 per cent fat. They added 0.75 per cent gelatin and the same quantity of salt to the drained curd. They heated the mixture to 150° to 175° F. and homogenized it at temperatures from 130° to 175° F. They obtained their most favorable results when the cheese was homogenized at high temperatures and high pressures, namely, 175° F. and 4000 pounds pressure. In general they found that increasing pressures and increasing temperatures for these treatments tended to decrease the firmness of the final product.

**Hot-pack process and control of composition.** The adjustment of the composition of Cream cheese made by the cold-pack process is achieved by blending bags or batches of curd and by adjusting the composition of the original mix. The products made by the hot-pack process can be similarly controlled but it also provides an opportunity to make a final and more exact adjustment of the composition of the batch after draining. The drained curd can be mixed with pasteurized cream, milk, condensed milk, skim milk, or condensed or dried skim milk to attain the desired fat and total solids content. This mixture, usually with added gums, can then be heated, homogenized, and packaged.

**Hot-pack process and use of low-fat mix.** Mixes that are made with less than 12 per cent fat produce curd that is inclined to be less smooth than that made with high fat mixes. When such low-fat curd is heated, mixed with suitable amounts of cream, and homogenized, the product becomes extremely smooth. When gums are added before homogenizing to prevent leakage of moisture in the package, the product simulates the properties of Cream cheese with high fat and low moisture, even when it actually contains less fat and more moisture than the amounts permitted in Cream cheese under existing definitions. These low-fat, high-moisture products must be called Neufchatel if they have less than 33 but more than 20 per cent fat and not more than 65 per cent moisture.

**Hot-pack process, salting and packaging.** Salt is added to the drained curd while it is being mixed and heated with cream, milk, and gums prior to homogenization. When the homogenized product flows from the machine it is ready to package.

Packages for hot-pack cheese are similar, or identical to those used for cold-pack cheese. These packages can be filled by mechanical equipment. The hot cheese flows as readily as freshly frozen ice cream. The high temperature of the hot-pack cheese as it enters the package tends to minimize the effects of accidental contamination with microorganisms which might cause spoilage. The semi-fluid condition of the cheese allows it to conform to the lining of the package; air is completely excluded. Absence of air in the package prevents the growth of mold, one of the chief causes of spoilage of Cream cheese. For these reasons the market life of hot-pack cheese in an air-tight, moisture-proof package is generally superior to that of cheese made by the cold-pack process.

Flavoring materials or condiments can be added to the hot-pack cheese before it is packaged. In this respect it differs from the cold-pack cheese only in the necessity of using flavoring materials that are not affected by high temperatures. When heat-sensitive flavoring substances are used, then the temperature of the product must be adjusted, within the limits of good packaging technique, to preserve the desired quality of the flavoring material.

**Yield of Cream cheese.** The yield of Cream cheese depends upon the composition of the original mix, the manufacturing

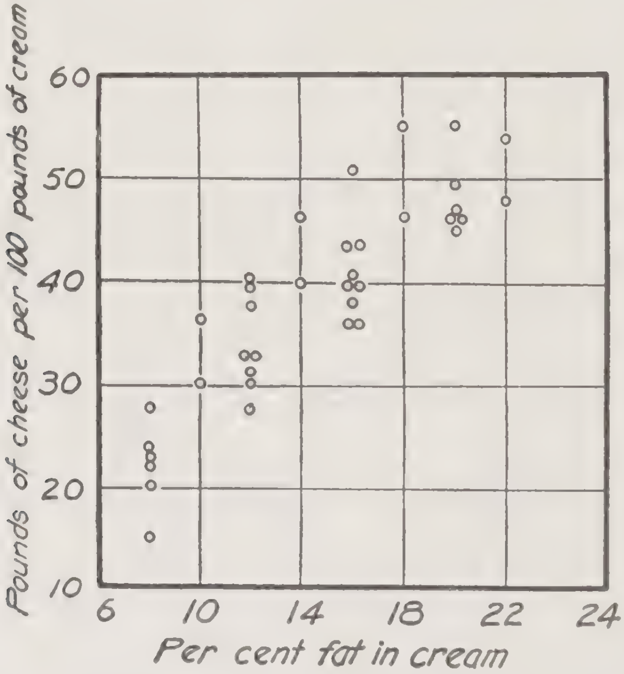


Figure 25:5. The yield of cheese from 100 pounds of cream increases as the per cent of fat in the cream increases. (*Roundy and Price, 1941*).

losses, the moisture content of the finished product, and the weight of products used in the standardizing or hot-pack operations.

Actual yields of drained curd from mixes varying in fat from 8 to 22 per cent fat were reported by Roundy and Price (1941). They used no milk concentrates in these mixes. Some of their data are presented in figure 25:5. Percentage yields were highest when high-fat mixes were used. The average number of pounds of cheese obtained per pound of fat in the mix increased as the fat in the mix decreased. When mixes with 8, 12, 16, and 18 per cent of fat were used, the yields averaged 2.96, 2.59, 2.42, and 2.18 pounds of cheese per pound of fat respectively. Such differences are powerful incentives favoring the use of mixes with the minimum fat necessary to produce cheese which meets the manufacturer's standard of quality.

## DEVELOPMENTS IN CREAM SPREADS

The blending of cream with milk solids-not-fat by homogenization has introduced new dairy products with some of the characteristics of Cream cheese. These products deserve the attention of the industry. Their legal status is not clear because they do not strictly conform to existing definitions of Cream cheese.

### Dahlberg (Geneva) Method

This unique process depends upon the changes which occur in the physical condition of fat and protein when cream is subjected to high homogenizing pressures at a temperature of 110°F. The fat gathers in large clusters, and the protein is said to undergo a form of coagulation. This process was invented and described by Dahlberg (1927). Later Dahlberg and Marquardt (1934) gave additional information on the process and described its application in the making of flavored spreads.

Under the present definitions of the Food and Drug Administration (1942) this product apparently is not qualified technically to be called Cream cheese. This new product is not drained to remove whey; the Federal definitions definitely state that the Cream cheese curd is drained after coagulation. Dahlberg and Marquardt (1934) pointed out that, although the new product did not comply with the federal definition, it did satisfy the minimum requirements in composition.

**Acid flavor.** In order to make 100 pounds of the Dahlberg cheese with an acid flavor, 93 pounds of sweet cream containing 40 to 42 per cent fat is used. To this cream are added 5 pounds of soluble dry skim milk, 0.75 pounds of common salt, and 0.5 pounds of powdered agar. These materials are added slowly and are thoroughly stirred into the cold cream. The mixture is then pasteurized at 180° to 185°F. for 5 minutes, cooled to 110°F., and to it is added 0.75 pounds of lactic starter. The batch is passed through a one-sixteenth inch strainer and is then homogenized at 3500 to 4000 pounds pressure. The homogenizer should have been previously sanitized and heated by running water through at 160°F. As the mixture leaves the homogenizer it has the consistency of soft butter or freshly frozen ice cream. It is packaged immediately in the final container or it may be placed in suitable molds, chilled and later cut into prints of suitable size and wrapped. Regardless of the packaging treatment, the product must be cooled to 70°F. and held at that temperature until the desired acid flavor has developed. The packages are then chilled and stored at 40°F.

**Flavored blends.** The Dahlberg process can be used to prepare cheese blends which do not require the use of starter. The same basic mixture of cream, dry skim milk, salt, and agar are used for these blends (Dahlberg and Marquardt, 1934).

**Cheese flavor.** Ripened cheese is used for flavoring the basic mixture of cream and other ingredients. About 25 pounds of well-ripened Cheddar or 15 pounds of Roquefort are substituted for equal amounts of the cream mixture base. The ripened cheese melts and disperses in the cream base when the heating temperature approaches 115°F. No emulsifying salts are necessary although they can be used in limited amounts without interfering with the physical changes during the homogenizing process.

**Food flavors.** Condiments and other food flavors may be used in the Dahlberg process. When pimiento or sweet pickle relish are used, they are added at the rate of about 20 pounds of it for each 80 pounds of the cream mixture. They are mixed with the cream base after homogenizing while the mixture is still hot. Olives, nuts, pineapple and other flavorous products may be used. Tart spicy flavors are generally preferred.

The flavored blends are packaged while hot and they are placed immediately at storage temperatures.

### Homogenized Cottage Cheese

Dahlberg and Marquardt (1934) pointed out that Cottage cheese and cheese with similar flavor might be used to secure the desired acid flavor in their cream base mixture without the addition of starter.

Reichart and Crowe (1941) studied several combinations of milk products with Cottage cheese to make a soft cheese like Cream cheese. They tried various mixtures of sour cream, sweet cream, Cottage cheese curd, condensed skim milk, and superheated condensed skim milk. Their most desirable combination consisted of ripened cream with 65 per cent fat and 0.45 per cent titratable acidity, Cottage cheese curd, and salt. They combined these ingredients to obtain 30 to 32 per cent fat, 43 to 46 per cent total solids. The mixture had a pH of 4.5 to 4.7. The blend was heated to 180° F. and homogenized at 2500 pounds pressure. It was forced directly from the homogenizer into the final package and then stored at 35° F. The flavor, body and texture of the finished product compared favorably with similar products on the market; the keeping quality was superior.

## BAKER'S CHEESE

Baker's cheese is a soft unripened cheese made from skim milk. It is made by the traditional Neufchatel process and is properly known as skim milk Neufchatel. It is slightly acid in flavor, smooth in consistency, but not as smooth as Cream cheese. The ideal cheese is free of lumps and hard particles of curd. Some manufacturers attempt to make a product like Baker's cheese by grinding Cottage cheese but it is practically impossible to duplicate the smoothness of Baker's cheese without using highly specialized types of mills.

Baker's cheese contains 65 to 78 per cent moisture and is practically free of fat. It is mixed with cream and used like Cottage cheese in the home. It is commonly used in the baking trade for making cheese pies and cheese cakes. This product has a good market in some of the larger cities of the United States, particularly east of the Mississippi.

Baker's cheese is usually made in a cheese vat although it can be made in containers of any size.

## CONDITIONS OF SETTING

**Milk.** Baker's cheese is best made from pasteurized skim milk. Either the holder method or the high-temperature short-time method is satisfactory. Pasteurization simplifies the manufacturing operation, it gives a cheese of superior keeping quality and uniformity, and it is a safeguard for the public health. The milk should be clean in flavor and fresh when it is used for this cheese.

**Rennet.** Both rennet and acid are used in coagulating the milk. Rennet is used at the rate of 10 ml. or one-third of an ounce for 1000 pounds of milk. It is diluted with at least 20 times its own volume of water just before it is added to the milk.

**Starter.** An active lactic starter is necessary for the successful manufacture of this product. It is used at the rate of approximately 4 pounds per 1000 pounds of milk when the long-setting process, or overnight setting period is used. When the short-setting process is used, the amount of starter approximates 50 pounds for 1000 pounds of skim milk. These amounts of starter are commonly adjusted to compensate for changes in such factors as: temperature variations during the setting period, differences in the activity of the starter, and the necessity for cutting the curd after longer or shorter intervals of setting to make the process fit better into plant operations.

**Temperature.** The temperature of the skim milk for the long-setting process is 70° to 72°F. The short-setting process requires a temperature in the skim milk of 90°F.

**Duration of the setting period.** Sufficient time must elapse during the period of setting to obtain the necessary rennet action and acid development. A firm curd usually forms before the acid develops to the desired level.

When the curd is ready for cutting and draining it is firm, jelly-like, and inclined to be brittle; it splits readily. At this time there is usually a small amount of free whey over the surface of the curd. This whey first exudes from the surface of the curd like beads of sweat; the amount may eventually cover the surface of the curd.

Acid development is the critical factor; it must be measured before the curd is cut. This is done by titrating the free whey which usually covers the surface of the curd. The acidity desired is 0.4 per cent or more. It is better practice to titrate the whey which can be separated from the curd by centrifuging it in a Babcock cream test bottle in the manner described for

Cottage cheese on page 389. The acidity of the whey which can be separated from the curd in this manner is equal to, or greater than, the acidity of the whey on the surface of the curd. Titration of the whey of centrifuged curd gives a better estimate of the acid development than measurements of the whey over the surface of the curd. This makes possible more careful control of acid to produce maximum yield and quality in the cheese.

The time required for the curd formation and acidity development is approximately 5 hours for the short-setting method and 14 hours for the long-setting process. These intervals can be varied at will by the manufacturer by controlling the amounts of starter and temperatures of setting.

## Removal of Whey

**Bagging the curd.** The removal of the whey is accomplished by draining the curd in sacks made of heavy muslin sheeting. These bags are commonly about 36 inches long and 24 inches wide when they are empty and spread out flat. No heat is applied to the curd at any time.

Probably the most common way of placing the curd in the draining bags is to dip it from the vat and pour it into the bags with curd pails. The bags are usually held open by one operator while the second operator dips the curd out of the vat and pours it into the open bag. Another way of getting the curd into the sacks is sometimes followed when one operator must fill the bags alone. The curd is cut with curd knives into small pieces which will flow through the gate of the vat directly into the bags. The size of the curd knives apparently makes no difference in the quality of the curd. A tilting vat is useful in this type of operation to hasten the flow of curd to the gate.

**Draining.** As each bag is filled with curd it is tied shut and piled on racks in a cheese vat or it is hung on a rack to drain. The bags of curd in the vat are spread out as much as possible in the early stages of draining. The whey escapes more rapidly when the greatest possible surface of each bag is exposed for draining. When the flow of whey tends to decrease, the bags are shaken and turned over. About 60 to 90 minutes after dipping the flow of whey can be hastened by piling the bags two or three high. This pile has to be turned over every half hour or hour to equalize the pressure on all bags and to obtain uniform draining of whey from all bags. The curd can be completely drained by repiling the bags in the vat. The draining operation can be shortened by pressing.

**Pressing.** Some operators complete the draining operation by piling the bags of curd on racks in a bin. Bags may be piled with alternate layers of ice. A weight may be placed on top of the pile. Occasionally a simple lever system is used to apply additional pressure to the sacks to expedite draining. The draining and pressing operations are complete when the moisture content of the curd approximates 75 per cent. Different markets require slightly different consistency in the curd.

**Salting.** The curd is salted lightly at the rate of 0.5 to 1.0 per cent; salt may be omitted entirely for some markets. Some plants use a roller-type curd mill to incorporate salt and to make the consistency of the curd uniformly smooth.

**Distribution.** Baker's cheese is packed in cheese cans, well-tinned 50-pound cream tins, or in lined and paraffined butter tubs for shipment to distant markets. Local sales can be handled in paraffined cartons. Such cartons should be filled only as they are needed. They are not suitable for long holding because they may absorb enough moisture to form air spaces between the curd and the carton; mold grows readily in these spaces.

**Yield.** The yield of Baker's cheese varies with the composition of the milk, the manufacturing losses in the whey, and the moisture content of the cheese. The yield ranges commonly from 14 to 18 pounds from 100 pounds of milk.

## NEUFCHATEL CHEESE, TRADITIONAL METHOD OF MAKING

The traditional type of Neufchatel cheese has many desirable qualities which commend it. It can be manufactured on the small scale where homogenizing equipment is not available. The cheese has the general properties of the Neufchatel and Cream cheese made by the cooked-curd process but it is not as smooth in consistency and is more acid in flavor. The manufacturing operations are practically identical to those used for Baker's cheese with the exception that Neufchatel cheese is always coagulated in small containers like shotgun cans or pails.

### Conditions of Setting

**Milk.** Whole milk or milk enriched to about 6 per cent fat is used for the non-cooked type of Neufchatel cheese. The milk is pasteurized, preferably at 145 F. for 30 minutes and cooled. It may or may not be homogenized before cooling.

**Rennet.** Rennet is added at the rate of 1 ml. for 100 pounds of milk. For measuring smaller quantities of rennet, it is usually most convenient to dilute a small measured amount, for example 1 ml., to 10 or 100 times its original volume. The amount of this dilute solution to furnish any small fraction of 1 ml. of rennet can then be easily and accurately measured. The rennet extract should be diluted with at least 20 times its own volume of water before it is added to the milk.

**Starter.** An active lactic starter is necessary for the production of the best product. It is added to the milk at the rate of approximately 0.4 per cent for an overnight setting period of 14 to 15 hours.

**Temperature.** The temperature of holding the milk during the setting period is 72°F. Rennet and starter are added in the pasteurizing vat where the temperature can be properly adjusted. The mixture is then placed in clean shotgun cans for coagulation. These cans are held in a room where the temperature is maintained at 72°F.

## Removal of Whey

The curd is ready to drain when the acidity of the whey is more than 0.37 per cent. There may be a little free whey formed on top of the curd during the setting period; this can be used in making the titration. A sample of whey for titration can also be obtained, if there is no free whey over the curd, by removing a few spoonfuls of curd and titrating the whey which collects in the depressions. If draining is attempted when the acidity is too low, the curd will be tough and rubbery; if it is too high, the flavor will be too sour and the manufacturing losses in the whey will be greater.

**Draining and pressing.** When the acidity is at the desired level, the curd is dipped with a ladle, or gently poured, into a draining bag such as those described for Cream cheese. The bag is laid on a rack and turned and shaken occasionally for a period of two or three hours. After this interval the whey will have ceased running freely and the curd will have enough body so that light pressure can be applied to the bags. The drainage of whey is slower if enriched milk is used. At no time should the pressure be great enough to cause the curd to ooze through the mesh of the cloth bag.

**Salting.** The pressing operation is finished when the moisture approximates 60 to 65 per cent and the consistency is like that of soft butter. The curd is packed in glass jars or wrapped in moisture-proof wrappers. It can be packed only for quick distribution in paraffined cardboard cartons. After a few days of holding in these cartons the cheese tends to shrink away from the sides. This makes conditions suitable for extensive mold growth. The cheese should be held at 35°F.

**Yield.** The yield of Neufchatel cheese made by this process approximates 15 to 18 pounds per 100 pounds of mix depending upon the composition of the milk used.

## PRESERVATION OF SOFT, UNRIPENED CHEESE

**Short storage.** Carefully made Cream, Neufchatel and Baker's cheese may be held for short periods of time at temperatures of 32° to 35°F. At such temperatures the life of the first two varieties made by the cold-pack method is reasonably assured for 10 to 14 days. If these varieties are subjected to the hot-pack process and placed in air-tight, moisture-proof packages they may be held at the same temperatures for approximately four weeks. Baker's cheese should not be held for more than one week. All three varieties of cheese are readily spoiled by attacks of yeasts and molds. Sanitation measures which decrease their yeast and mold content increase the market life of these products.

**Freezing temperatures.** The influence of freezing temperatures on Cream and Neufchatel cheese is undesirable. The defrosted cheese is objectionably rough and mealy. Flavor characteristics are not materially damaged but the physical condition of the cheese makes it unmerchantable.

Ellenberger (1919) showed that it was possible to preserve the food value of Baker's cheese by holding it in frozen storage. He reported that it could be held for a few months in lined and paraffined butter tubs or well-tinned cans. Pasteurizing the milk from which the cheese was made, making a dry curd, and chilling the curd before packing, resulted in better keeping quality.

**Preservation by vacuum.** Sherman (1927) packed soft cheese under a vacuum and found that mold growth was prevented entirely. The principle of this method of preservation is applied commercially. Packaging machines flow steam over the top of the glass container of cheese to exclude air while the cap is pressed on and sealed in place. Vacuum is produced when the steam condenses. Anaerobic organisms in the cheese may still cause spoilage in this package.

**Care of draining bags.** Draining bags can be a dangerous source of contamination in the making of Cream, Baker's, and Neufchatel cheese, if they are not properly cleaned and sterilized. Yeasts, molds, and other microorganisms grow readily on cloths which are not in good sanitary condition. Such contamination causes objectionable flavors and odors in the cheese and materially shortens the market life of the product.

Roundy (1939) used sodium metasilicate solution very successfully in the routine handling of draining cloths. He first removed all visible traces of the cheese by rinsing the cloths in warm water, washing them in a weak solution of trisodium phosphate, and finally rinsing them with liberal amounts of clean water. The cloths were then submerged in a 2 to 3 per cent solution of metasilicate. The cloths were weighted down to keep them completely covered. They were held at room temperature. The cloths were rinsed in clean water just before they were used in order to remove the metasilicate. Roundy followed this routine for six months and found the results entirely satisfactory in terms of bacteriological condition of the cloths, quality of the cheese, and the physical condition of the cotton cloths. The sodium metasilicate solution had no detectable harmful effect on the strength of the cotton fibers.

Some manufacturers follow the practice of washing cloths by ordinary laundry methods and then holding them in chlorine solution under refrigeration until they are again needed. This treatment is effective if the strength of the chlorine solution when the cloths are removed is still above 50 to 100 parts per million. Careful operators rinse these bags in clean water before using them although some consider this unnecessary if the cloths are centrifuged in a drier to remove the chlorine solution.

## REFERENCES

Dahlberg, A. C. (1927). J. Dairy Sci., *10,* 106.

Dahlberg, A. C. and Marquardt, J. C. (1931). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 226.

Ellenberger, H. B. (1919). Vt. Agr. Expt. Sta., Bul. 213.

Fisk, W. W. (1925). Bestov Lactonews. Cherry-Bassett Corporation. June, 1925.

Food and Drug Administration (1942). Federal Register, *7,* 10755.

Marquardt, Julius Charles (1927). J. Dairy Sci., *10,* 309.

Matheson, K. J. and Cammack, F. R. (1918). U. S. Dept. Agr., Bul. 669.

Matheson, K. J., Thom, C. and Currie, J. N. (1914). Conn. (Storrs) Agr. Expt. Sta., Bul. 78.

Reichart, E. L. (1936). Neb. Agr. Expt. Sta., Bul. 303.

Reichart, E. L. and Crowe, L. K. (1941). J. Dairy Sci., *24,* 544.

Roundy, Zola Doyle (1939). Thesis, University of Wisconsin, Madison, Wisconsin.

Roundy, Z. D. and Price, Walter V. (1941). J. Dairy Sci., *24,* 235.

Sherman, J. M. (1927). Glass Container, *6,* No. 5:18.

Strezynski, G. J. (1947). (to De Laval Separator Co.) U. S. Patent 2,432,829. Dec. 16.

Zakariasen, B. M. and Combs, W. B. (1941). J. Dairy Sci., *24,* 543.

# CHAPTER 26

# WHEY AND ITS UTILIZATION

The cheese industry utilizes only a portion of the milk solids for the production of the principal product, cheese. The by-product, whey, contains nutritious food elements and compounds which are needed for food and industrial purposes. When the whey is wanted for some useful purpose it may become a powerful factor in establishing the competitive strength of the factory. Unwanted whey, under certain circumstances, may become a serious liability. Efficient utilization of whey is the objective of thoughtful operators. This discussion is intended to call attention to some of the uses and problems of handling whey.

## PROXIMATE COMPOSITION

About half of the milk solids of whole milk remain in the whey when milk is made into Cheddar cheese. This has been shown by the work of Van Slyke (1894) as presented in table 5:2. He studied Cheddar cheese factory operations and summarized data for two years to show that the dry matter of whey from these factories averaged 6.96% total solids consisting of 0.36% fat, 0.84% proteins, 5.76% lactose and salts. Webb and Whittier (1948), in reviewing the utilization of whey, stated that typical cheese whey can be expected to contain 6.9% total solids, consisting of 0.3% fat, 0.9% protein material, 4.9% lactose, 0.6% ash, and 0.2% lactic acid. These values are variable because the composition of milk and cheese making procedures are not constant.

The vitamins of whey vary with the amounts in the milk used in making the cheese and with the nature of the cheese making operations. Vitamin A remains with the fat of the milk; the small portion of it that gets into whey is removed when the whey is separated to obtain the whey cream. Vitamins $B_1$, $B_2$, and C are water soluble and a large proportion of each is found in the whey. Vitamin $B_2$, riboflavin, is probably the only vitamin present in amounts to be of real interest from the nutrition standpoint. Vitamin D is not present in amounts sufficient to prevent rickets when fed to animals. Lesser amounts of other vitamins are present in whey.

Webb and Whittier (1948) gave the following estimates of the individual ash constituents present in whey: potassium oxide, 0.188%; sodium oxide, 0.075%; calcium oxide, 0.071%; magnesium oxide, 0.018%; ferric oxide, 0.001%; phosphorus pentoxide, 0.110%; chlorine, 0.107%; and sulfur trioxide, 0.029%.

The calcium and phosphorus in whey have considerable nutritional value especially because in the presence of lactose they are apparently more readily available. The ash constituents of whey impart a salty flavor to whey concentrates; this flavor limits the utilization of these concentrates in certain human foods. Garrett (1947) stated that the salt content of whey can be altered by ionic exchanges. Whey treated in this manner can be made into concentrates which are very pleasing to the taste.

The whey proteins are of high quality and are particularly valuable in livestock feeding because they supplement the grain proteins with necessary amino acids. Practically all essential amino acids are present in whey proteins in suitable proportions to support normal growth and reproduction.

Milk sugar, the carbohydrate in whey, aids in the assimilation of calcium and phosphorus. In the process of digestion it tends to form a desirable acid reaction in the intestinal tract. Lactose is valuable in poultry feeding because it tends to prevent coccidiosis.

TABLE 26:1. PRODUCTION OF CHEESE, WHEY AND DRIED WHEY IN THE UNITED STATES, 1937-46

(Sources of data, U.S.D.A., 1948, and Wis. Dept. of Agr., 1945)

| *Year* | *Total Cheese Manufactured* * | *Whey (Estimated* ***)* | *Dried whey* |
|---|---|---|---|
| | (1000 lb.) | (1000 lb.) | (1000 lb.) |
| 1937 | 648,825 | 5,839,425 | 66,582 |
| 1938 | 725,325 | 6,527,925 | 47,384 |
| 1939 | 708,527 | 6,376,743 | 56,341 |
| 1940 | 785,490 | 7,069,410 | 90,996 |
| 1941 | 956,161 | 8,605,449 | 111,316 |
| 1942 | 1,112,314 | 10,010,826 | 124,479 |
| 1943 | 993,294 | 8,939,646 | 110,158 |
| 1944 | 1,017,247 | 9,155,223 | 141,553 |
| 1945 | 1,116,772 | 10,050,948 | 135,920 |
| 1946 | 1,100,770 | 9,906.930 | 147.953 |
| 1947 | 1,177,669 | 10,599,021 | 157.583 |

* Excluding Cottage, Pot and Baker's cheese.

** Estimate assumes 9 lb. whey resulted from manufacturing 1 lb. cheese.

## PRODUCTION

Approximately nine pounds of whey remain after the manufacture of each pound of cheese. The total production of whey since 1944 has approximated ten billion pounds annually. These estimates are based upon the whey from all varieties of cheese made from whole milk. Cottage cheese and related types yielded another one and one-quarter billion pounds of whey annually. The general trend of whey production from whole-milk cheese from 1937 to 1946 is shown in table 26:1.

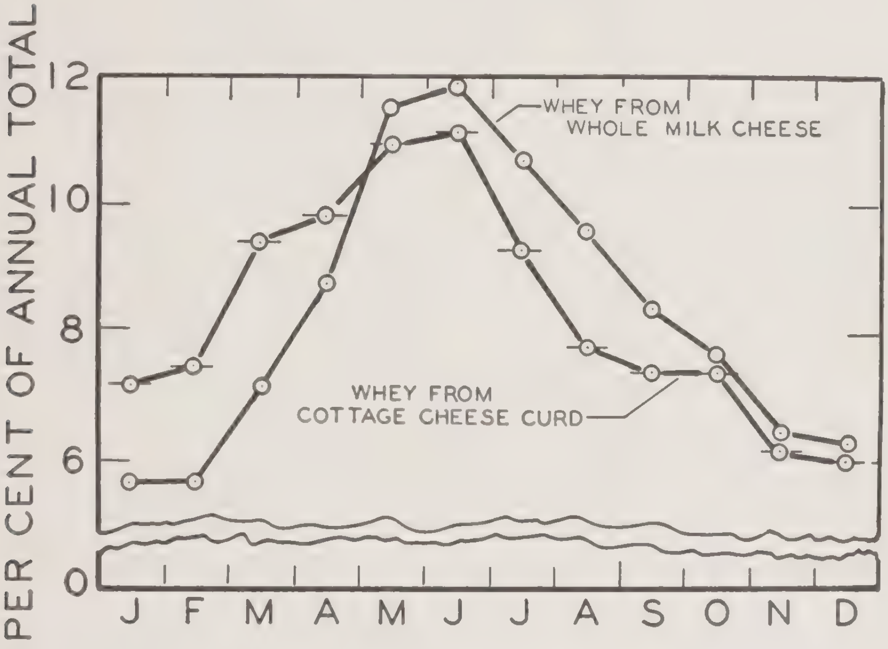
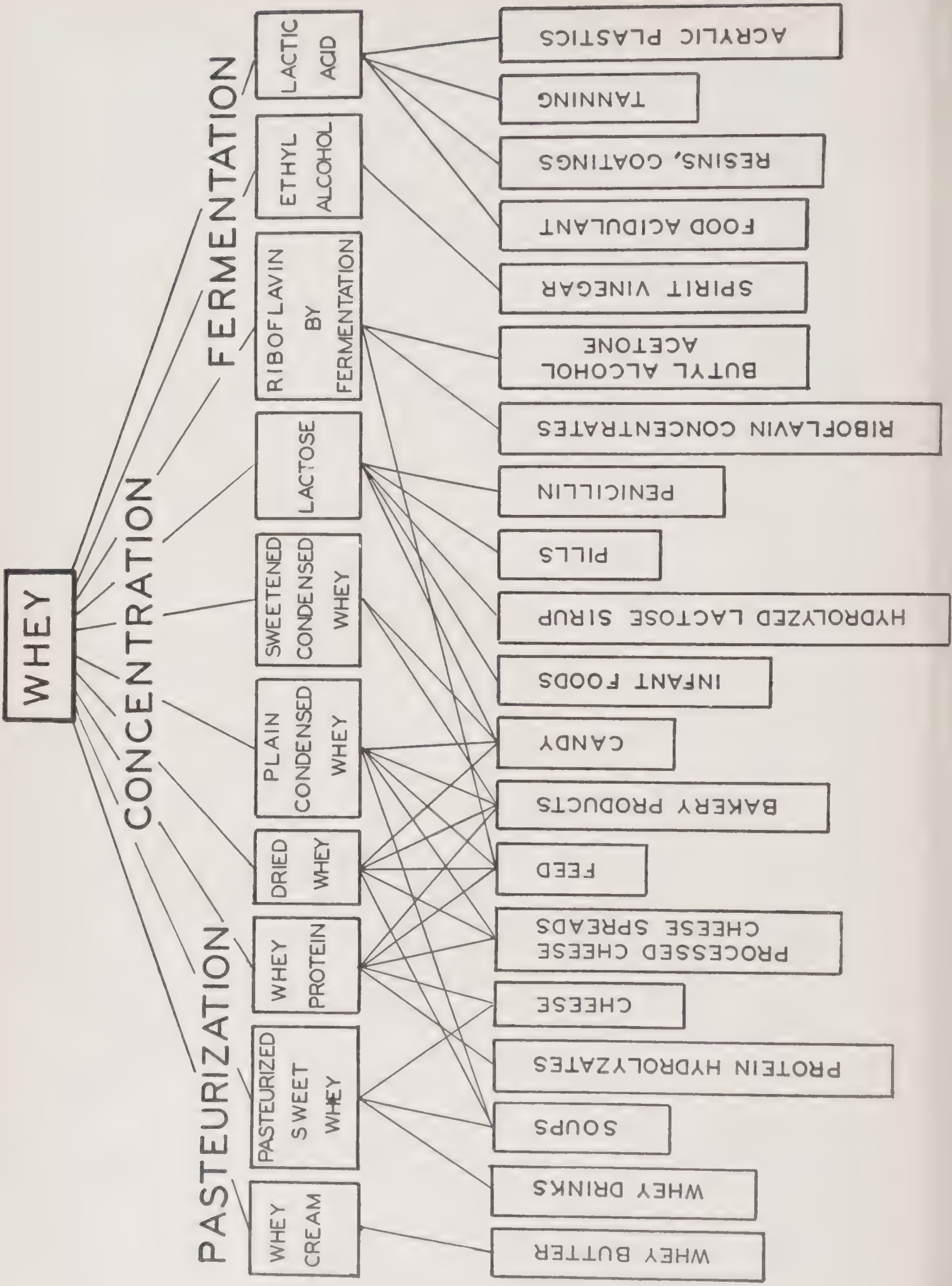


Figure 26:1. The production of whey is highly variable from month to month. This variability makes it difficult to utilize all whey efficiently.

The production of whey is highly seasonal. Figure 26:1 illustrates the extent of this variation. The seasonal trend is responsible in part for the difficulty of providing an adequate use for fluid whey. Farm utilization of whey for livestock requires most whey during the latter part of the summer and early fall when whey production is decreasing. Seasonal fluctuation in whey production presents a problem in utilization in areas where livestock is a minor factor and the whey is used instead by processors. The variation is such that some whey cannot be utilized during the flush, if the plant is to be operated at, or near, peak efficiency for the whole year.


WHEY
FERMENTATION
CONCENTRATION
PASTEURIZATION
LACTIC ACID
ETHYL ALCOHOL
RIBOFLAVIN BY FERMENTATION
LACTOSE
SWEETENED CONDENSED WHEY
PLAIN CONDENSED WHEY
DRIED WHEY
WHEY PROTEIN
PASTEURIZED SWEET WHEY
WHEY CREAM
ACRYLIC PLASTICS
TANNING
RESINS, COATINGS
FOOD ACIDULANT
SPIRIT VINEGAR
BUTYL ALCOHOL ACETONE
RIBOFLAVIN CONCENTRATES
PENICILLIN
PILLS
HYDROLYZED LACTOSE SIRUP
INFANT FOODS
CANDY
BAKERY PRODUCTS
FEED
PROCESSED CHEESE CHEESE SPREADS
CHEESE
PROTEIN HYDROLYZATES
SOUPS
WHEY DRINKS
WHEY BUTTER

## Whey Utilization

One objective of every efficiently operated cheese factory is to dispose of whey profitably. Farmers in the principal cheese producing areas use more than half of the whey for feeding livestock. Somewhat less than one-third of the whey is used for manufacturing purposes. The remainder of the whey may be considered to be wasted; it represents about one-tenth of the total.

**Methods of using whey.** The principal outlet for whey is in the livestock industry. It is used as the fresh liquid whey by farmer patrons of factories. It is dried and used in mixed feeds. Some of the dried whey is purchased by farmers who use it in place of liquid whey. Whey, concentrated or dried under suitable sanitary conditions, is used for human food. There are many uses and potential uses for whey; most of these uses need research to develop them. Webb and Whittier (1948) visualized the flow sheet of whey utilization shown in figure 26:2. The practical scope of these uses is limited only by the relative costs of competing raw materials and by the market acceptance of the whey products themselves.

**Size of whey processing plants.** Webb and Whittier (1948) stated that the profitable manufacture of concentrated products of whey by condensing or drying requires from 40,000 to 100,000 lb. of whey per day. When equipment is already available and when whey cannot be disposed of in any other way, then it may be profitable to concentrate as little as 10,000 lb. of whey daily.

The larger whey processing plants depend upon outlying cheese factories for raw material; such plants may require a minimum approaching 100,000 lb. per day for profitable operation. Transportation of whey long distances from the factories to the central plant is an important item in their cost of operation. Labor, supplies, and overhead for such large operations may be low per unit of product manufactured. Hauling of the whey for long distances introduces quality control problems which usually make it necessary to manufacture the centralized whey into feed for livestock.

The smaller whey processors depend for their supply upon the whey from their own cheese operations or possibly that from a few neighboring factories. Such operations may lend themselves more readily to the production of whey products for human use. As the demand for such products increases, whey processing operations in the lower volume bracket will tend to become more practical. Patent restrictions still apply to some of the processes, particularly to those of whey drying.

The production of lactose, protein hydrolyzates, and fermentation products from whey involve highly technical procedures and special equipment. The market provided for whey in these products at the present time does not interest the investor whose main attention must be given to the production of the primary product, cheese. Webb and Ramsdell (1944) pointed out, for example, that the profitable manufacture of lactose, one of the simpler isolation operations, must include evaporator, filter press, and sugar centrifuge, and requires a volume of not less than 75,000 lb. of whey per day.

**The whey disposal problem.** Unused whey is a liability to the cheese factory. It must be hauled away from the factory or vented into a sewage system; either method is expensive.

The hauling of unwanted whey from the factory requires tanks, trucks, a suitable place of disposal, and the expenditure of labor and power. Areas commonly used for dumping purposes are fields, abandoned mines or quarries, swamps, and streams. Dusty roads have been sprinkled with whey as emergency dumping areas; the results of continuing this practice can only be imagined. If dumping areas are sufficiently isolated so that fermentation of the whey is not a community nuisance then it can usually be practiced for a length of time depending upon the absorbing power of the soil, and the quantity of the whey. Running or dumping whey into a stream, unless it is a large one, is almost certain to cause trouble for the factory operator. The stream pollution problem has already reached such levels in most parts of the country that this outlet should not be considered.

Venting whey into the sewage system places a tremendous load upon the biological ability of the system to ferment the carbohydrate and decompose the protein materials of the whey. The whey dumped into a sewage system can constitute only a small portion of the entire capacity of the system. Small cities and villages are becoming increasingly aware of this limiting relationship. Most of them require the factory to keep unwanted whey out of the sewer system. Minimizing the milk or whey solids content of the plant sewage decreases the investment in the system necessary to dispose of the plant wastes.

Under some circumstances, therefore, it may actually be cheaper to use the whey for some unprofitable purpose and so remove it from the premises, rather than to resort to hauling and dumping or to attempt to dispose of it in a sewage system.

## WHEY FOR HUMAN FOOD

**Whey fat.** The fat in whey is removed by mechanical separation. The whey cream is most commonly used in the making of butter, either alone or mixed with regular cream. Guthrie (1928) found that butters made from whey cream and regular cream of comparable quality were practically alike in keeping properties and quality. He concluded that the two types of cream could be mixed together without ill effects, providing the whey cream was at least equal in quality to that of the regular cream. Thomsen (1936) warned that the residual rennet in whey cream might coagulate the casein of normal cream if temperature and times of holding were favorable to the action of the rennet. Pasteurization of whey cream destroys rennet activity.

Whitehead (1944) investigated the unusual possibility of using whey cream by adding it to the milk to be used for making cheese. He heated the whey cream to 200°F. for 30 minutes to destroy bacteriophage. He used it to furnish additional fat which ranged in amounts from 6 per cent to 27 per cent of the fat in the original milk. It is surprising that he observed no difficulty in making the mixtures into cheese and found no change in quality of the maturing cheese. The extra yield of cheese approximated 1.2 times the weight of fat added; this fact alone will not commend the procedure because the fat is worth more in the form of cream.

Whey cream of good quality, can be used instead of regular cream in the making of Cream cheese. The lack of casein in whey cream permits its use in mixtures with acid foods in which regular cream would coagulate.

**Cheese-like whey products.** Cheese makers have traditionally attempted to use whey for making foods resembling cheese. Some new developments in this field of utilization indicate the desirability of further studies of these possibilities.

**Whey cheese** made by Scandinavians and widely known by the names, **Mysost** or **Primost**, is marketed in small amounts. It is made by evaporating the moisture from whey by boiling and stirring it in open pans. When the liquid has been reduced to a thick consistency, it is poured into jars or molds to solidify.

**Albumin cheese**, commonly known as **Ricotta**, or **Ziger**, is made by precipitating the albumin of sweet whey. Unskimmed whey may be fortified by the addition of skim milk, or skimmed whey may be fortified by the addition of whole milk; the milk or skim milk is added at the rate of approximately 10 per cent. The whey, or mixture of milk and whey, is heated to 165° to 195° F. Sufficient amounts of sour whey or dilute acetic acid are added to precipitate the proteins. A successful precipitation of the proteins causes the curd to float on the surface of the vat or kettle. The curd is ladled into perforated metal molds, drained, chilled and eaten fresh, or dried and used for grating purposes.

Whey protein has been used experimentally in the making of Roquefort-like cheese (Reed, 1946). Preliminary results indicate that the procedure is feasible.

**Plain concentrate.** Webb and Hufnagel (1946) described the manufacture of plain condensed whey. They advocated the use of pasteurized whey, concentration under vacuum to 68 per cent solids, or 36.7° Baumé at 115°F., cooling rapidly to 90°F., and seeding and stirring to control the effects of lactose crystallization during the cooling of the concentrate.

Concentration of whey to high total solids may cause the lactose to start crystallizing in the condensing pan. When the total solids are 65% or more, this crystallization may form a heavy paste in the pan which cannot be removed in the normal manner. Such paste may have to be dug out of the pan. Such

TABLE 26:2. BAUMÉ AND SPECIFIC GRAVITY VALUES FOR CHEESE WHEY CONCENTRATE
(Data by Webb and Hufnagel, 1946)

| *Total solids* | *Density at 115°F.* | | *Total solids* | *Density at 115°F.* | |
|---|---|---|---|---|---|
| | *°Bé.* | *Sp. gr.** | | *°Bé.* | *Sp. gr.** |
| % | | | % | | |
| 30 | 15.6 | 1.121 | 54 | 28.9 | 1.249 |
| 32 | 16.7 | 1.130 | 56 | 30.1 | 1.262 |
| 34 | 17.8 | 1.140 | 58 | 31.2 | 1.274 |
| 36 | 18.9 | 1.150 | 60 | 32.3 | 1.287 |
| 38 | 20.1 | 1.161 | 62 | 33.4 | 1.299 |
| 40 | 21.2 | 1.171 | 64 | 34.5 | 1.312 |
| 42 | 22.3 | 1.182 | 66 | 35.6 | 1.325 |
| 44 | 23.4 | 1.192 | 68 | 36.7 | 1.339 |
| 46 | 24.5 | 1.203 | 70 | 37.8 | 1.353 |
| 48 | 25.6 | 1.214 | 72 | 38.9 | 1.367 |
| 50 | 26.7 | 1.226 | 74 | 40.1 | 1.382 |
| 52 | 27.8 | 1.237 | 76 | 41.2 | 1.397 |

* Specific Gravity $= \dfrac{145}{145 - {}^\circ\text{Bé.}}$

conditions can be avoided by starting each run with a clean, lactose-free pan, and by striking the batch before the concentration exceeds the desired limit of total solids. Table 26:2 shows the Baumé degrees associated with various percentages of whey solids.

Webb and Hufnagel (1946) recommend that the concentrate should be drawn from the pan while it is still a clear syrup. It can then be cooled rapidly to about 90 F., seeded with lactose, and run directly into the final containers. The concentrate cools to form a smooth-bodied paste. Some manufacturers are placing the concentrate in cardboard cartons lined with a water-proof film. These containers can be easily stripped from the semi-solid paste.

The keeping properties of whey concentrate vary with its acidity and the conditions of storage. The titratable acidity of the sweet whey after concentration is approximately 10 times the value before concentrating. The acidity is high enough so that the product endures holding for about 10 days without refrigeration. If the whey is soured before concentration so that the pH is 4.5 or less, Webb and Hufnagel (1946) indicate that the product can be kept for months providing the containers are air-tight enough to inhibit mold growth.

Table 26:3 reproduces data of Webb and Hufnagel (1946) to show the changes in the pH, titratable acidity, and solids content of whey as the result of concentration. The titratable acidity increases almost in direct proportion with the increase in the total solids content of the concentrate.

The process cheese industry uses large quantities of plain

TABLE 26:3. EXPERIMENTAL DATA OF WEBB AND HUFNAGEL (1946) OBTAINED DURING THE PREPARATION OF FIVE BATCHES OF CONDENSED CHEESE WHEY

| Plain Whey | | | | Condensed Whey | | | | |
|---|---|---|---|---|---|---|---|---|
| *Type of Whey* | *Reaction* | *Titratable acidity* | *Total solids* | *Reaction* | *Titratable acidity* | *Density at 115°F.* | | *Total solids* |
| | pH | % | % | pH | % | °Bé. | Sp.gr. | % |
| Swiss | | | | | | | | |
| sweet | 6.12 | 0.11 | 6.64 | 4.75 | 1.14 | 37.6 | 1.350 | 68.39 |
| soured | 4.97 | 0.25 | 6.65 | 4.57 | 2.47 | 37.3 | 1.346 | 73.28 |
| Cheddar | | | | | | | | |
| sweet | 6.15 | 0.13 | 6.63 | 5.37 | 1.25 | 33.7 | 1.303 | 63.34 |
| soured | 4.44 | 0.36 | 6.77 | 4.18 | 3.86 | 40.1 | 1.382 | 74.65 |
| Cottage | 4.61 | 0.52 | 6.62 | 4.02 | 5.28 | 38.3 | 1.359 | 68.26 |

condensed whey. The increased production of cheese foods and cheese spreads in recent years has provided an attractive market for whey concentrate. Other uses of whey concentrate for human food are still being studied; much work remains to be done to develop the uses of this product in such foods as bread, cake, cookies, and candy. One of the chief faults of whey concentrate for such uses is its salty, characteristic flavor.

**Sweetened concentrate.** Ramsdell and Webb (1938) described the manufacture of sweetened condensed whey. The whey is pasteurized. Sugar is added in amounts to equal the weight of whey solids in the batch. The mixture is concentrated under vacuum to 38 per cent sucrose, 38 per cent whey solids, and 24 per cent water. The batch is cooled to 95°F., seeded with lactose crystals and stirred for 1 hour to control crystallization. The concentrate is placed in cans or barrels. At 76% solids this concentrate has a Baumé reading of 38.4° at 122°F.

Ramsdell and Webb found that sealed containers were best to prevent mold growth. They stated that this concentrate may be added to any food where both whey solids and sugar are desired. They used it experimentally in jams, whips, sweet baked goods, and candies.

**Dried whey.** The use of whey in dried form for human food is not common as yet. This is caused partly by problems of manufacturing and partly by problems of utilization. When whey is treated like milk in drying, it absorbs moisture and cakes because the milk sugar crystallizes. This caking problem has resulted in the development of several patented procedures for making dried whey. Webb and Whittier (1948) have classified into four groups the processes for controlling crystallization of lactose in the making of dried whey: 1) concentration to 70 per cent solids, crystallization of lactose, and drying of the semi-solid material; 2) drying of the whey and allowing water to be absorbed to force crystallization of the lactose; 3) concentration to the point where the water remaining equals that required for hydration of the lactose; and 4) concentration of whey, inducing crystallizing of the beta lactose at a temperature above 200°F. and finishing the drying of the concentrate at over 200°F.

Dried whey for human food has been used experimentally in the same food products as plain condensed whey. It has other possible uses in the preparation of dried foods, or mixes in which dried whey may be substituted for dried skim milk.

Dried whey is made by several processes. It is concentrated under vacuum, to approximately an 11 to 1 ratio, cooled, sometimes seeded with lactose, held while the lactose crystallizes, and finally it is spread on screens and dried in a tunnel drier. Tunnel drying has been used for making dried whey for livestock. The spray process of drying requires the application of the special treatments to control lactose crystallization. This process is used for making dried whey for human consumption.

The roller process for drying whey presents many mechanical difficulties. Roller dried whey is commonly used for livestock. Waite (1941) found that sweet whey with an acidity of 0.15 to 0.25%, collected in a molten mass on the scraper knife of the roller drier, formed a dry skin, and then broke up and fell from the knife in small pieces. Jack and Wasson (1941) found it necessary to add a film-forming material to the whey to obtain satisfactory drying properties. Equal parts of sweet whey and sweet skim milk formed a satisfactory drying mixture. The addition of 8% of spray dried skim milk was also a good drying aid; drum-dried skim milk was not satisfactory. They used ground and sifted cereals, such as corn starch, wheat flour, oats, or barley as drying aids. These were added at the rate of 3 to 3.75 lb. per 100 lb. of whey. They found that increased acidity in the whey increased the difficulties of drying. Neutralization with sodium hydroxide almost entirely restored the original drying properties; Waite (1941) preferred calcium hydroxide for neutralizing. Jack and Wasson stated that acid-type cottage cheese whey behaved like cheddar whey in the drying process.

**Other products of whey.** Whey can be fractionated to yield protein hydrolyzates, lactose and lactic acid. Each of these products has possibilities in the field of human nutrition. The hydrolyzates have found some application in pharmaceutical fields. Lactose is used in infant foods, and as a coating for pills. It can be hydrolyzed to give a slightly sweeter form according to Ramsdell and Webb (1940). The fermentation of lactose gives lactic acid which can be used in the acidification of certain foods. These food products represent minor outlets for the food value of the huge quantities of whey produced each year in this country.

Other human food uses of whey are suggested in figure 26:2. One of the least exploited, but a use with good possibilities, is the manufacture of whey drinks.

## WHEY FOR STOCK FEED

More than half of all the whey produced is used for feeding farm animals. When all patrons are located within a short distance from the factories, as is generally true in old established cheese areas, then most of the liquid whey is used for feed. The establishment of whey drying and condensing operations in such areas to use the surplus of whey in certain seasons tends to reduce the feeding of liquid whey. Some farmers prefer to sell the whey for cash. Dried whey and whey concentrate are often sold to cheese factory patrons whose farming practices require the feeding of whey. The relatively high cost of whey solids in this form discourages its extensive use.

Price, Bohstedt, and Rupel (1944) summarized information on the uses of liquid whey for livestock. They stated that calves do well on clean, pasteurized, fresh, sweet whey but not as well as they do on skim milk. A high protein concentrate grain mixture is required for use with the whey until the calves are about six months old. For pigs, the liquid whey is supplemented with some protein-rich feed. Whey is worth approximately one-fourth of a bushel of corn for feeding hogs; for hogs in pasture the value is slightly less, while for hogs in dry lot its value is slightly greater.

Dried whey and plain condensed whey are used for livestock food either directly or in mixtures with grain. Dried whey can be used in poultry rations in amounts up to approximately 10 per cent without inducing laxative effects. Its lactose content is believed to be helpful in preventing coccidiosis. The riboflavin content of dried whey has a beneficial effect on growth and health of chicks. Plain condensed sweet whey is a perishable product and must be held under refrigeration if it is to be stored for any length of time. Whey can be soured to an acidity approximating 1%, then condensed for animal feed. At a concentration of approximately 10 to 1 the total solids of the concentrate equals 60 to 65%. The acidity of the concentrate preserves it.

Whey is used in making grass silage. For each ton of grass it is necessary to add 35 pounds of dried whey or its equivalent in whey solids in concentrated form. Liquid whey can be used but the grass must first be dried sufficiently to absorb the liquid whey.

## Whey for Industrial Uses

The lactose in whey is used in the fermentation industry. The products of this industry are chiefly riboflavin, ethyl alcohol, butyl alcohol, and lactic acid. The uses of these substances in industry are indicated in figure 26:2.

Penicillin is produced by the growth of certain strains of molds on lactose. The manufacture of penicillin has provided an outlet for large quantities of lactose in recent years. The relatively high cost of lactose and the fact that other substrates can be used for this purpose suggest that less, rather than more, lactose will be used for penicillin.

It is possible to use whey or fractions of whey for industrial or non-food purposes. Many raw materials which can be used instead of whey for such industrial outlets are, in general, less expensive.

The superior nutritive value of the dry matter content of whey in terms of proteins, minerals, lactose, and vitamins, would seem to encourage the utilization of whey for food rather than for industrial purposes.

## Sanitation Problem in Utilizing Whey

Whey to be used for human food must be given special care. Utensils, pipelines, pumps, tanks, and other equipment must be constructed as carefully as any other fluid milk handling equipment. Every precaution must be observed to keep whey for human food clean and to minimize bacterial growth in it. Leaders in industry are formulating standards for defining handling treatments in specific terms.

Whey to be used for livestock may be returned to the farmers without treatment other than heating. This whey should be handled carefully from the sanitary standpoint. Processors of whey require, or may provide, special facilities at the factories in order to attain these objectives. Some salt and water from making operations may be mixed with the large volume of whey for livestock: excessive amounts of either are unnecessary and undesirable. Large amounts of salt are distasteful to livestock and may actually be injurious. The addition of small amounts of water to whey may be necessary but is not desirable for any use: water must be added when all farmers insist on taking home a full can for every can of milk delivered.

Whey for livestock should be returned in containers other than the cans used to deliver the milk. This is essential for sanitary reasons because it is difficult or impossible to be sure that the cans are properly cleaned and sterilized before they are filled again with milk. Returning whey in the emptied milk cans is forbidden by regulations of some states.

Tanks mounted on haulers' trucks are used in some areas to return fresh whey to the farms. Such tanks and trucks must be maintained in a sanitary condition.

Whey tanks inside or outside of the cheese factory must be properly constructed, well located, and kept thoroughly cleaned. Whey tanks outside the factory should be placed on a concrete apron which is sloped to a suitable drain. Every effort should be made to minimize spilling of whey around the tank or in its immediate vicinity. Whey soaked soil provides breeding places for flies and creates an undesirable odor both of which detract from the attractiveness of the factory as a food manufacturing establishment.

## References

Garrett, O. F. (1947). J. Dairy Sci., *30,* 536.

Guthrie, E. S. (1928). N. Y. (Cornell) Agr. Expt. Sta., Bul. 468.

Jack, E. L. and Wasson, A. J. (1941). J. Dairy Sci., *24,* 85.

Price, W. V., Bohstedt, G., and Rupel, I. W. (1943). Wis. Agr. Expt. Sta., Ext. Serv. Circ. 340. (Revised, 1944).

Ramsdell, G. A. and Webb, B. H. (1938). J. Dairy Sci., *21,* 305.

Ramsdell, G. A., and Webb, B. H. (1940). J. Dairy Sci., *23,* 525.

Reed, O. E. (1946). J. Milk Tech., *9,* 173.

Thomsen, L. C. (1936). J. Dairy Sci., *19,* 503.

U. S. Department of Agriculture (1948). Production of manufactured products, 1946 and 1947. Bur. Agr. Economics, Washington, D. C. May and Dec., 1948.

Van Slyke, L. L. (1894). N. Y. (Geneva) Agr. Expt. Sta., Bul. 65—New series.

Waite, R. (1941). J. Dairy Res., *12,* 71.

Webb, B. H. and Hufnagel, C. F. (1946). Nat. Butter and Cheese J., *37,* No. 12:34.

Webb, B. H. and Ramsdell, G. A. (1944). Nat. Butter and Cheese J., *35,* No. 7:18; *35,* No. 8:18.

Webb, B. H. and Whittier, Earle O. (1948). J. Dairy Sci., *31,* 139.

Whitehead, H. R. (1944). New Zealand J. Sci. & Technol., *26,* No. 4: (Sec. A):201.

Wisconsin Department of Agriculture (1945). Wisconsin Crop and Livestock Reporting Service, Bul. 250.

## CHAPTER 27

# THE CHEESE FACTORY

The success of a cheese factory depends on its organization, business management and many other factors. Some of these other important considerations are: location, site, plant layout, plant construction, and factory sanitation.

### LOCATION

**Milk supply.** It is essential that the cheese factory should be located where there is an adequate supply of milk of suitable quality. Such a supply cannot be assured by the number of cows in the area, unless the milk production of these animals is definitely committed to the factory. Competitive outlets for the same milk must be considered. Good roads and costs of transportation influence the availability and quality of the milk supply. The type of operation must be considered. A supply of 5000 pounds per day might be sufficient to support plant operations if the milk were used in making specialty items, or if the product were cured and sold only in the retail market. On the other hand, a supply of at least 50,000 pounds per day would be necessary to support an efficient operation for making cheese and utilizing all by-products.

**Distance from market.** The distance from market cannot always be measured in miles. If retail sales are important, then a short distance between the factory salesroom and the street or highway may be a limiting factor. Condition of roads, trucking service, railroad service, as well as the point of delivery are significant. The markets for the products of the plant need to be favorable as well as accessible.

**Public opinion.** The reactions of the town people as well as the rural people in the community of the factory enterprise may make it a success or a failure. They must be ready to cooperate with the factory management. This may be evidenced by their willingness to sponsor or help in the organization of the factory. If dairying is not the typical way of farming in the community then the personal incentives which encourage milk production must be considered. Farm organizations can be powerful allies, or opponents, of local enterprise.

## SITE

The site of the factory or its proposed location are important. Among the facts to be considered are: water supply, drainage, and the surroundings.

**Water supply.** An abundant supply of pure water is essential for refrigeration, cleaning, and other purposes. Regardless of the source of supply it should be tested regularly by the proper public health authorities to make certain that it is healthful. This precaution may not be necessary except in emergencies if an approved city water supply is used. Tests should be made as often as necessary to be certain of the safety of the supply; a six months interval between tests is desirable as a minimum, daily tests might be essential at times when floods endanger the source of water for the factory.

**Drainage and sewage disposal.** Drainage conditions influence factory surroundings and plant operations. Natural drainage or grading of the land around the factory building should eliminate pools of water or low spots. A properly located factory may be able to make use of natural drainage to facilitate the construction of the sewage disposal system when such provisions must be made to handle the cheese factory wastes.

Cheese factory wastes of milk solids come from inefficient or improperly operating equipment, such as leaking vat gates, overflowing whey tanks, and open separators which vent whey foam or splash onto the floor. Emptying into the drains the press drippings, rinsings from vats, tanks, and pasteurizers increases the milk solids which must be treated in the factory sewage system.

Dean (1946) presented a comprehensive report of the findings of the Task Committee on Dairy Waste Disposal of the Milk Industry Foundation. The committee found that claims against the dairy industry for improper disposal of wastes included: devaluation of property, injury of livestock, discomfort, loss of health, destruction of fish and wild life, destruction of plant and plankton life, and general nuisance. Dairy plants may be jointly responsible with the municipality for a nuisance created by the municipal system into which their sewage is vented.

Dean and his committee stressed the necessity of reducing both the volume and strength of plant wastes. They cited one dairy plant with a biological oxygen demand (B.O.D.) in its waste of 260.5 pounds. By eliminating wastes the plant decreased this value by 72%. This reduced to 28% the sewage system capacity required by that plant. They made specific recommendations to reduce the volume and strength of plant wastes; the following apply to operations in a cheese factory which has a condensing pan in addition to the usual cheese making equipment:

A drip saver should be provided to collect drainage from milk cans after dumping and pre-rinsing. Drippings and pre-rinsings can be used for animal feed.

Liquid level controls are needed to prevent overflows of milk or whey at all tanks, vats, upper and lower cooler troughs, and the like.

Provisions are needed to take care of milk or whey when breakdowns occur. These include extra pumps, and adequate storage space for milk and whey to prevent emergency dumping.

Leakage or splash is unnecessary from sanitary fittings, pumps, vat gates, outlet valves, worn out packings, cooler surfaces, cooler troughs, feed pipes or feeder troughs for pasteurizers.

Foaming of liquids may be eliminated by replacing open type separators, and by preventing air leaks in pump suction lines, pump packing, or pump rotary seals. Splashing in filling tanks or vats causes excessive amounts of foam.

An entrainment separator should be provided on a condensing pan to minimize carryover of milk solids. An electronic liquid level control can be connected with an alarm and vacuum breaker to prevent the pan from boiling over.

Whey tanks should be of adequate size to prevent loss of whey or foam. Steel tanks are preferable to prevent leakage. A gasoline type valve on the whey line is desirable to prevent spilling of whey from the open hose.

Drippings from vats and presses should be collected in stainless steel buckets and added to the bulk of the whey for proper disposal.

Sanitary pipelines should be installed so that they can be drained into buckets at the end of the run. Vats, tanks and pasteurizers should be pitched to drain completely into buckets.

Dean's committee discussed waste treatment methods very briefly. They emphasized that the degree of treatment should be determined by study of the waste flow, waste strength, and stream conditions. They enumerated certain elementary treatment methods: 1) keep milk out of the drains; 2) provide an aerated equalizer tank to hold 1.5 times the volume of the daily maximum waste load at the peak of the year; by-pass all clean, cooling water and storm water; 3) do not vent hot water into a stream; cool it by spraying or venting to a private pond; 4) slightly contaminated water from the condensing pan may be vented to the stream if the evaporator is properly designed and equipped with entrainment separators or devices to prevent the boiling over of the pan; and 5) discharge from toilets and wash rooms must go to separate septic tanks not used for dairy wastes, unless the plant is connected with city sewers.

The Dean committee recommended the *trickling filter* for more complete treatment of the dairy plant waste. This device consists of a "trickler" which is made of crushed rock or other coarse materials of similar character, like gravel or slag that permit passage of air. The trickler is preceded by an equalizer tank. By suitable means the effluent from the trickler can be recirculated and eventually run into the sedimentation tank where the bacterial slough-off of the trickler is collected and from which the effluent is vented into the stream.

The Dean committee commented briefly on other methods of treating dairy plant wastes:

The *activated sludge process* is more costly than the trickling filter in both initial cost and operation.

*Two trickling filters* connected in series are better than one. They reduce the B.O.D. more completely than the same filter area in one unit.

The *chemical precipitation method* depends upon the addition of materials to coagulate the proteins in the waste. The sugars remain. The chemical sludge is cumbersome to remove. The operator must have a fair knowledge of chemistry.

The *Guggenheim process* is a combination of the chemical precipitation and activated sludge methods. The operation is more complicated and expensive than the trickling filters.

The *Mallory process* is a patented procedure that uses the activated sludge idea plus some expensive refinements.

Bloodgood (1948) reviewed the problem of waste disposal. His bibliography includes 194 references. He summarized his discussion by saying that objections are not limited to any single system. The principal problems are those of high costs of building, operating, and maintaining the disposal plants. Some systems have biological problems, others chemical problems. These difficulties are not insurmountable. He agreed with the Dean committee on the importance of minimizing losses of milk solids in the sewage. He visualized decreased costs and improved efficiency resulting from further studies of the waste disposal problem.

The treatment and disposal of dairy wastes is so important to each plant that technical engineering advice, based on a careful study of the individual factory, should be obtained. Authorities in state government who are concerned with the public health can usually furnish directories of competent engineers and organizations able to assist the factory in meeting this problem.

**Surroundings.** It is desirable that the factory should be situated at a distance from neighborhood contamination. Sources of dirt and smoke, like dusty highways, railroads, barnyards, or feed lots are objectionable. Certain industries near the cheese factory may produce unusual troubles and defects. Contamination of yeasts from a nearby brewery, for example, proved to be an insurmountable problem for a plant manufacturing a soft, unripened cheese.

Complete closing of food plants to the outside air is an objective in the minds of food regulatory officials. Air filters and the establishment of air pressures in the plant slightly higher than those outside offer means of protecting the interior of the plant from outside contamination.

## BUILDING

**Exterior.** The factory can be an attractive part of a community. It must be attractive if it is to command attention for retail sales. This attractiveness is attained in part through proper design and construction. Good design and construction can be made even more attractive by neat surroundings that result from proper care and landscaping.

One story type of construction is commonly favored because loads on the floor are transferred to the ground, rather than supported by structural parts of the building; trucks and conveyors replace stairs and expensive elevators; capital investment is less if land is available to spread construction; and building maintenance and plant expansion are simplified.

**Interior.** It is not the purpose of this text to discuss plant design and construction in the detail which a prospective builder or buyer needs. It is desirable, however, to indicate certain essentials which contribute to the general efficiency and sanitation of plant operations.

**Plant layout.** Details of plant design that affect the success of factory operations include provisions for: 1) orderly movement of materials into, through, and out of the plant; 2) sanitary control of the product; 3) efficient use of man power; 4) ease of supervision; and 5) increasing capacity.

Movement of products must be orderly and not interfere with other steps or processes in the operation; for example, the shipment of cheese from the plant should be possible without having the driveway for incoming milk trucks blocked off by the truck that happens to be loading cheese.

Sanitary control of some operations requires the establishment of protected zones or areas in the design of the plant. Examples are: the desirability of isolating the starter-making operations in a separate room to prevent air-borne contamination. Other spaces which should not be directly connected to the make room include toilets, locker and shower room, whey storage, and boiler room. The factory itself should be separate from truck storage, living quarters, and sewage disposal units. Other desirable separations in this combination are immediately apparent and need not be listed.

Efficient use of manpower is an essential effect of good plant design. Reasonable costs to achieve this goal can be recovered quickly in labor saving. Labor reacts unfavorably to useless or difficult motions. An example of the first is the needless separation of two operations for which one man must be responsible. An example of the second is the fact that men do not work as well or as safely on wet floors. It is possible by careful planning to segregate washing of utensils and many other wet operations so that dry floors can be maintained in other areas for greater efficiency, comfort, and sanitation. Spaces which should be adjacent to the make room for greatest efficiency include the milk intake, laboratory, pasteurizing room, cleanup room for wet operations, refrigerated storage, and dry storage. The milk intake should be adjacent to the laboratory, pasteurizing room, and perhaps the office. Locker room, showers and toilets should be together. Dry storage space should be close to the freight receiving and shipping platforms. Other spaces which might well be adjoining will suggest themselves for special needs.

Ease of supervision provided by good plant design tends to eliminate errors, decreases costly mistakes in processing and makes good management more effective in controlling plant operations and labor utilization.

Good plant layout provides for future expansion with minimum destruction of existing facilities. Features in the plant which will continue to serve in the expanded operation can be placed in the original plant so that they need not be moved; boiler plant, compressor and other refrigeration equipment might be included in this category.

Many of these desirable features of plant design, and some undesirable ones, can be found in the diagrams of Cheddar

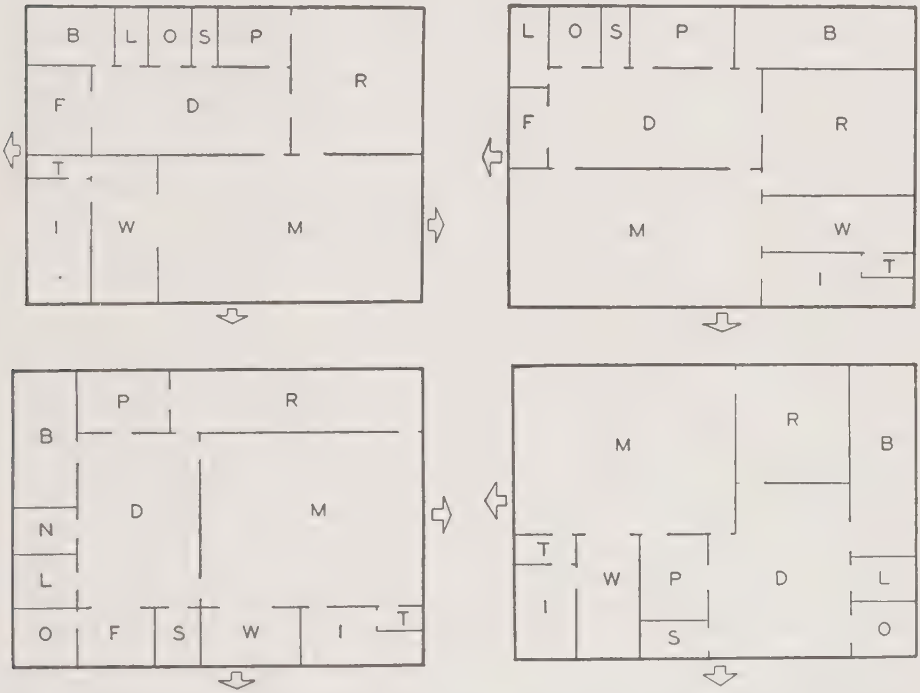


Figure 27:1. These four diagrams show several possible arrangements of the essential floor space in Cheddar cheese factories. These are not floor plans, although the general proportions are roughly correct. The diagrams are intended to call attention to desirable features such as flow of materials through the plant, association of certain rooms, and separation of other rooms and work areas. Arrows point in the directions in which future expansions may develop without disturbing heavy facilities like boilers, refrigerators, and the like.

*Key to identifying letters*

B—Boiler, fuel, shop
D—Dry storage, paraffining
F—Freight, shipping
I—Intake
L—Lockers, showers, toilets
M—Making room
N—Work shop, machine tools
O—Office
P—Packaging
R—Refrigerated storage
S—Starter
T—Laboratory
W—Space for pasteurizing, separating, washing equipment

cheese factory layouts in figure 27:1. These are not to be interpreted as plans; the spaces are not proportioned to any specific needs. Each diagram has good and bad points typical of compromises frequently necessary in planning of buildings. In the diagram in the upper, left corner of figure 27:1, for example, the movements of freight across the freight platform will interfere with the movement of milk to the intake if trucks have to use the same driveway; on the other hand, this diagram indicates good possibilities for efficient movement of products.

## MINIMUM FACTORY REQUIREMENTS

Minimum factory requirements were formulated and published by the "Joint Committee on Research of the Cheese Industry of Wisconsin." (1941) This committee consisted of representatives of the Wisconsin Cheese Makers Association, the National Cheese Institute, Inc., the Wisconsin Department of Agriculture, and the University of Wisconsin. Their requirements are presented here in a condensed form:

**Factory premises.** Well kept and free of objectionable dust and odors.

**Whey tank.** Ample in size, clean, free from odors, kept in sanitary condition in clean surroundings.

**Water supply.** From a city supply or from a well suitably protected against polution according to the Wisconsin Well Construction Code; tested once each year.

**Sewage disposal.** Disposed of to prevent any odors at plants.

**Factory building.** (a) *Exterior.* In good repair and painted if made of wood.

(b) *Interior.* Make room, exclusively for handling milk and its products; no pet animals permitted in such room; walls, ceiling, and floors in good repair, clean, and sanitary.

(c) *Doors and windows.* Effectively screened or protected self-closing doors, to exclude flies from rooms where milk is handled or exposed.

(d) *Lighting and ventilation.* Well lighted and provided with ventilation equipment if necessary.

(e) *Intake.* All openings to make room screened or closed.

(f) *Curing room.* Separate room of adequate size, reasonable temperature control, shelves removable for washing, and containing no vegetables or unnecessary materials or equipment.

(g) *Salting room.* Table and tank in good repair, clean;

brine, clean, wholesome and full strength; room, orderly and free of unnecessary materials and equipment.

(h) *Storage room.* Good repair, orderly, free of unnecessary materials and useless equipment.

(i) *Boiler room.* Separated by tight partitions and self-closing doors from rooms containing dairy products or supplies, orderly, in good repair, free of useless equipment and materials.

(j) *Toilet facilities.* Clean, convenient facilities in good repair; clean water, soap or washing powder, sanitary towels; not directly connected with rooms where dairy products are exposed, manufactured or stored; self-closing doors; outdoor toilets, sanitary, properly located and maintained according to Board of Health recommendations.

**Factory equipment.** (a) Equipment and utensils for handling milk and its products shall be smooth, sanitary, unbroken.

(b) Surfaces contacting milk or milk products shall be self-draining and easily accessible for cleaning.

(c) Equipment shall be in good repair, no open seams or corrosion.

(d) New equipment shall be seamless, or made with properly soldered, welded or expanded joints.

(e) All piping and pumps for conveying milk or milk products for human use shall be of sanitary type.

(f) Interiors of pumps, pipelines, fittings shall be of size and shape to permit thorough inspection; bent or dented piping which interferes with cleaning does not comply.

(g) Wooden equipment for handling butter or cheese shall be sound and smooth.

(h) Equipment and utensils for handling dairy products shall be properly washed, scalded, and stored in a clean, dry place.

(i) Equipment not used regularly shall be placed in storage room.

(j) Proper equipment shall be provided for carrying satisfactory starter.

(k) Brooms or metal sponges shall not be used in the vat while milk or curd is there.

(l) Inside tank for milk or whey to be skimmed shall be easily accessible for cleaning, in a lighted, ventilated, sanitary place.

**Personnel, cleanliness and health.** (a) Persons handling milk, milk products, milk equipment, milk containers shall keep body and head covered at all times with clean garments and cap; hands shall be clean.

(b) No smoking in milk handling and manufacturing rooms.

(c) Employees shall meet health requirements of State Board of Health.

### FACTORY SANITATION

The minimum factory requirements which have just been listed suggest that in order to have a sanitary plant: (1) the building and equipment should be in good repair; (2) the factory should be clean and orderly; and (3) the workers should be clean and healthy.

**Reasons.** There are four important reasons for proper plant sanitation; they are: control of quality, the reputation of the business in the community, compliance with food production regulations, and greater efficiency of operations.

Plant sanitation provides one of the surest means of quality control. Lack of cleanliness probably ranks first among causes of inferior dairy products. The farmer who delivers milk to an unsanitary plant finds no incentive there to improve his own efforts. Maintenance of milk quality at such factories is practically impossible. Proper plant sanitation not only simplifies production of products of high quality but actually is a means of attracting better raw materials which aid directly in quality maintenance.

The reputation of the business in the community is directly influenced by plant sanitation. The members of the community who see the plant regularly, and those to whom the products of the factory are sold are impressed by the degree of cleanliness exhibited by the factory. An orderly, clean factory is invariably a better and more highly respected business establishment.

Food regulations require clean surroundings for the manufacture of food products. The Federal Food, Drug, and Cosmetic Act is very specific in this respect. It indicates that a food is considered to be adulterated if it is made under conditions whereby it *may* be contaminated. Proper plant sanitation is a simple method of meeting the primary requirements of food regulatory officials.

Greater efficiency in factory operations is attained by proper plant sanitation. It is easier and more pleasant to work in a clean plant, so labor is more productive. Time is saved in an orderly plant because equipment and tools are in their proper places ready to be used when needed. A clean, orderly plant is a safer place to work because there is less danger of slipping on unclean and wet floors, tripping over misplaced tools or equipment, or falling over miscellaneous articles on stairs or in dark halls.

**Responsibility for a clean factory.** The problem of keeping a factory clean is not difficult if those who are responsible can *see* dirt. This seems to be inherently a personal characteristic perhaps acquired only in the early training and home surroundings of the individual. Each individual in the factory has a definite function to perform.

The manager of the factory, or the person in charge of the work of others in the factory, must be alert, interested in the details of clean-up operations, and conscious of the presence or absence of cleanliness and order in the plant. He must point out items to be taken care of; he should assign the responsibility of such items to the care of an individual; he must see that the responsibility is discharged; and finally he should make every effort to simplify the difficult clean-up jobs by making necessary changes in building, equipment or labor utilization. This routine is even helpful in the plant where only a maker and a helper are working together. In a large factory a supervising committee on sanitation may offer suggestions to management. A trained inspector from outside the plant can also perform this supervising function effectively, if his reports are acted upon by those with ultimate authority.

## REFERENCES

Bloodgood, Don E. (1948). Sewage Works J., *20,* No. 4:695.

Dean, William A., Jr. (1946). The Association Bulletin, Dec. 17, 1946. Milk Industry Foundation, Washington, D. C.

Joint Committee on Research of the Cheese Industry of Wisconsin (1941). Cheese Reporter, *66,* No. 4:7.

# CHAPTER 28

# ANALYTICAL METHODS

The various analytical procedures presented in this chapter are described and discussed under five main headings: (1) the Babcock test for fat in milk, cream, and by-products; (2) tests for fat, moisture, salt, and extraneous matter in cheese; (3) tests for acidity in milk, whey, and cheese; (4) the Sanders and Sager tests for phosphatase in cheese and milk; and (5) miscellaneous tests.

Tests for measuring the quality of milk are discussed and described in Chapter 8.

## BABCOCK TEST FOR FAT

The Babcock test for fat is used in cheese factories to measure the percentage of fat in milk, whey, whey cream, and cheese. The monetary value of milk, whey cream, and sometimes cheese is determined by the amounts of fat in these products. The efficiency of utilizing fat delivered in the milk is important to every careful operator. The proportion of the milk fat retained in the cheese reflects the skill of the maker, the composition of the milk, the quality of the milk, and the influence of the method of manufacture.

Some states require a demonstration of the skill of the operator of the Babcock test for fat and issue a license to those who qualify. Practically every state has some regulations which are concerned with the measurement of fat in milk (Heinemann, et al. 1947). State agencies in charge of enforcement of regulations pertaining to testing for fat will furnish information on these regulations to those who request it.

The necessary glassware, centrifuge, scales, and acid for making Babcock tests for fat in dairy products can be purchased from any reliable dairy equipment or supply company.

### Babcock Test for Fat in Milk

**Sample.** The sample of milk collected at the weighing stand over a period of 7, 10, or 14 days is known as the **composite**

**sample**. It consists of small portions, commonly equal in size, that are withdrawn from the weigh tank each day immediately after the milk is dumped from the farmers' cans into the tank. The daily sample of milk is placed in a tightly stoppered bottle which contains one or two tablets of corrosive sublimate. These tablets are made especially for this purpose and contain a red dye to indicate that the milk has been denatured. After the milk has been transferred to the sample bottle, it is swirled gently, not shaken, to mix the milk with the preservative. The composite samples are refrigerated to keep them in better condition for testing. Regulations vary but they commonly require holding of the samples at temperatures above freezing but below 60° F.

### Apparatus and reagent

The apparatus required for the Babcock test for fat consists of the standard Babcock test bottle which is usually made with graduations from 0 to 8% in divisions of 0.1%, 17.6 ml. pipette which delivers 18 g. of milk, 17.5 ml. acid measure, Babcock centrifuge, dividers or calipers to assist in reading the fat column, and a water bath for tempering tests to 130° to 140°F.

Sulfuric acid of 1.82 to 1.83 specific gravity is the only reagent used in making the test. This acid dissolves the milk-solids-not-fat, heats the mixture at the same time, and releases the fat from its normal emulsion. When this mixture is whirled at the proper speed in the centrifuge the fat is completely separated.

### Procedure

1. Have the temperature of the milk to be tested at 60° to 70° F. Mix the sample thoroughly by pouring it back and forth a few times from one container into another. Do not incorporate air into the milk while mixing it. If lumps of fat persist in the milk, melt them by warming the sample to about 96° F. Some regulations require cooling to 70° F. before the sample is measured for testing. Theoretically this is correct, but the cooling is usually omitted because the error is negligible and because it is difficult to cool the composite sample without further separation of the fat.

2. Measure 17.6 ml. of milk in the milk pipette; insert the end of the pipette into the neck of the Babcock test bottle and allow the pipette to empty itself. Blow the last drop out of the pipette.

3. Use sulfuric acid at a temperature of 60° to 70°F.; slowly add to the milk 17.5 ml. of the sulfuric acid; rotate the bottle as the acid is poured into it so that any milk in the neck of the bottle will be washed down into the body of the bottle by the acid.

4. Mix the acid and milk with a swirling motion for at least two minutes or until the mixture is uniform in color and contains no particles of curd. Mechanical mixers are available to do this work. They do it better than can be done by hand.

5. Place the test bottle in the centrifuge; counterbalance it with another test bottle. Close and start the centrifuge. Whirl the test for 5 minutes after the centrifuge is up to speed.

The correct speed varies with the diameter of the wheel of the centrifuge. The diameter is measured with the cups in the horizontal position. The distance from the inside of any cup through the center of the wheel to the inside bottom of the opposite cup is the diameter of the centrifuge. The speed of rotation should conform to the following:

| | | | | | | |
|---|---|---|---|---|---|---|
| Diameter in inches.... | 12 | 14 | 16 | 18 | 20 | 22 |
| Revolutions per minute | 980 | 900 | 850 | 800 | 760 | 725 |

6. Stop the centrifuge after it has whirled 5 minutes at the proper speed. Add soft water at 130°F. to bring the level of the liquid to the base of the neck of the test bottle. Centrifuge for 2 minutes.

7. Add soft water at 130°F. to raise the top of the fat column well within the range of the graduations in the neck of the bottle. Centrifuge for 1 minute.

8. Place the bottle in the water bath for 10 minutes at 130° to 140°F. Adjust the level of water so that the fat column does not project above the water line. Discard any test if it is difficult to read, if the column contains charred or curdy material, if it is indistinct, or if it is not a clear yellow or amber color.

9. With the aid of dividers measure the length of the fat column from the bottom of the lower meniscus to the top of the upper meniscus. Without changing the dividers, hold the lower point against the 0 point on the fat scale and read the percentage of fat indicated on the scale by the upper point of the dividers.

## BABCOCK TEST FOR FAT IN CREAM

### Equipment and reagents

The equipment and reagents required in testing cream for fat are: cream test bottles of 9 gram or 18 gram capacity, torsion balance, 9 gram or 18 gram weight, acid measure, pipettes, Babcock centrifuge, water bath, dividers, glymol, sulfuric acid with specific gravity 1.82 to 1.83.

### Procedure

1. Mix the sample by stirring until it is smooth and homogeneous. Warm it to 100°F. if necessary.

2. Balance a clean, empty, cream test bottle on the torsion balance by counterbalancing with another cream test bottle and the tare weight.

3. Place the 9 gram (or 18 gram) weight on the pan and balance it by adding the necessary amount of cream to the bottle on the opposite pan.

4. Add about 10 ml. of acid to a 9 gram sample, or 15 ml. to an 18 gram sample, or enough so that after complete mixing the color of the cream and acid mixture resembles that of coffee with a little cream added.

5. Add about 10 ml. of soft water and mix.

6. Centrifuge for 5 minutes, add soft water at 130°F. to bring the level of the liquid to the base of the neck.

7. Centrifuge for 2 minutes and add soft water at 130°F. to bring the fat column into the graduations in the neck of the bottle.

8. Centrifuge for 1 minute; place the cream test in the water bath for 10 minutes at 130° to 140° F. Adjust the water level so that the fat column is below the water line. Discard tests if they are difficult to read, if the fat column contains curdy or charred material, or if the fat column is not clear yellow or amber in color.

9. Add a few drops of glymol to the top of the fat column before reading the test in order to level the meniscus on the top of the fat column.

10. Read the test with the aid of dividers as described in the testing of milk for fat.

11. Multiply the percentage of fat observed in the column by 2 when a 9-gram sample is used in an 18-gram bottle.

## Test for Fat in Whey, Skim Milk, or Buttermilk

Factory operators who hope to account for all of the fat in the whey should use the Mojonnier method. Fat-like substances included in the reading of the Babcock fat test of the whole milk escape in the whey. These substances do not appear in the column of the fat test for whey but are included in the ether-extractable material in the test for fat by the Mojonnier method and other similar laboratory analyses.

Hansen, et al. (1945) acting as a committee of the American Dairy Science Association reported on the merits of centrifugal testing methods for estimating the fat content of whey, skim milk and buttermilk. They used the Mojonnier test as a standard for comparison. They found that as the fat content of these products increased the agreement of the centrifugal and Mojonnier methods improved. None of the tests gave exact agreement with the standard Mojonnier test. The committee recommended the American Association method, the original Minnesota method, and the Pennsylvania method.

The American Association method for testing whey from Cheddar, Blue, Edam, and Swiss cheese, and for buttermilk and skim milk is as follows:

### Equipment and reagents

1. Use regular Babcock testing equipment and glassware, a 9 ml. pipette, and a burette graduated in divisions of 0.1 ml.
2. Use 18 gram, 0.5% and 0.25% skim milk test bottles.
3. Use normal butyl alcohol and sulfuric acid of usual strength, 1.82 to 1.83 specific gravity.

### Procedure

1. Measure with a burette 2 ml. of the normal butyl alcohol and place it in the skim milk test bottle to be used.
2. Measure 9 ml. of whey (or skim milk or buttermilk) with a pipette and place it in the test bottle with the normal butyl alcohol. Mix well.
3. Add 7 to 9 ml. of the sulfuric acid and mix thoroughly.
4. Centrifuge the bottle and its contents for 6 minutes at the prescribed speed of the centrifuge; add water to bring the contents of the bottle to the base of the neck of the bottle.
5. Centrifuge 2 minutes more and add enough water to bring the column of fat within the range of the graduations on the neck of the bottle.

6. Centrifuge the bottle for 2 minutes; place in a water bath at 135° to 140°F. for 5 minutes.

7. Multiply the reading of the test bottle by 2.

## CHEESE ANALYSIS

Wilster, et al. (1937, 1940) submitted outlines of methods for measuring fat, moisture, and salt in hard and soft varieties of cheese. Their recommendations have been considered in preparing the outlines of the analytical procedures which follow.

**Sampling hard cheese.** Either wedge-shaped or plug samples may be used. The wedge sample extends from the edge to the center of the cheese and from top to bottom. The inedible rind portion of the wedge is excluded and the remainder of the wedge is ground three times in a food chopper or grater, mixed, and placed in a tightly closed jar.

Plugs for samples are drawn perpendicularly from the flat surfaces of the cheese. The plugs are drawn from the centers of the flat surfaces, one from the top and the other from the bottom of the cheese. Each plug extends half way through the cheese. One inch of the rind end of each plug is returned to the cheese to close the hole (Winder, et al., 1948). The plugs are cut into small pieces by pushing them quickly through a one-sixteenth mesh screen into the sample jar. The sample is mixed thoroughly and the jar is kept tightly closed except for the instant when a portion of the sample is removed for weighing.

Samples are analyzed as soon as possible. If it is necessary to hold them, they are kept at approximately 40°F.

### BABCOCK TEST FOR FAT IN CHEESE

The apparatus and reagents used in the fat test for cheese are identical to those used for the fat test for cream.

#### Procedure

1. Balance a clean, empty, cream test bottle on the torsion balance by counterbalancing it with another and with the tare weight on the balance.

2. Weigh 9 grams of cheese into the cream test bottle.

3. Add about 10 ml. of water at 130°F. or more.

4. Measure 17.5 ml. of sulfuric acid and add it in two or three portions to the cheese and water in the test bottle. Mix carefully and thoroughly after each increment of acid is added

in order to avoid excessive boiling of the mixture. Continue shaking the bottle after all the acid is added and until all of the cheese is dissolved. Hold the bottle in boiling water if necessary to obtain complete solution of all particles of cheese.

5. Finish the test and read the results in the manner described for the fat test for cream.

6. Multiply the percentage of fat observed by 2 when a 9-gram sample is used in an 18-gram test bottle.

## TESTING CHEESE FOR MOISTURE

The sample for testing cheese for moisture is taken, prepared, and held until ready for analysis in the manner described for preparing the cheese for the fat test.

### Equipment

Equipment for testing cheese for moisture consists of a sensitive balance, a drying oven, a desiccator, and suitable drying dishes.

**Balances.** The accuracy of the balances used determines to a great extent the accuracy of the results. The preferred type of torsion balance has tare weights and double beams. One beam is graduated to 10 grams in 1-gram divisions, the other is graduated to 1 gram in 0.01-gram divisions. These balances must have a sensitivity which permits a deflection of the swinging pointer 1 division when 20 milligrams (0.020 grams) are placed on either pan of the scale when it is loaded to capacity. For best results with such balances, the amount of cheese sample for drying should be 5 to 10 grams.

An analytical balance, chainomatic type, is best for fast, accurate weighing of moisture samples. Such balances are commonly found only in carefully equipped laboratories where many analyses of cheese are run each day.

The torsion balance can be used like an analytical balance for weighing many samples in quick succession. This is done by first balancing the scales with the tare weights with the pans empty and with both riders of the graduated beams on their 0 marks. The large tare weight is fastened with the thumb screw to prevent shifting in operating. The small tare weight does not change position readily, but its position should be recorded if necessary. The dishes to be weighed are placed on the *left* pan of the scales. Counterbalancing gram weights are placed on the right pan of the scales and the final balancing of the dish is completed with the two riders on the graduated beams of the balances.

**Desiccator.** The desiccator provides a chamber in which clean, hot dishes and dried samples can be cooled in a moisture-free atmosphere. The desiccator consists of an air tight chamber for holding the dishes and a space beneath for the drying agent which may be anhydrous calcium chloride, concentrated sulfuric acid, or one of the type of prepared desiccants that can be regenerated by heating.

**Drying dishes.** Dishes for the moisture test are commonly made of aluminum. A satisfactory size is approximately 2 to 2.5 inches in diameter and 1.25 to 1.5 inches deep. They are provided with covers. Pyrex beakers are excellent for use in drying cheese. The 30 ml. size is well adapted for use in laboratories where the sample used does not exceed 5 grams. They may be used with or without covers but for accurate work should be covered during weighings. Single service aluminum cups are also available. Every dish should be clearly numbered for identification of samples.

**Ovens.** The electrically heated oven with an automatic thermostat to control the temperature is most commonly used. There are three common types of these ovens. The convection type has the heating element in the bottom or at the sides of the heating chamber. These heating elements activate the movement of the air by convection. Temperature differences of 10° F. have been observed between various shelves of such ovens. These ovens are usually relatively low in cost and find most general application in laboratories where exact results are not expected.

The second important type of oven has a vacuum chamber which is surrounded by heated air or oil. These ovens are generally carefully made and have elaborate controls. They may be evacuated by high or low vacuum pumps. They usually have a limited capacity and are used in laboratories where the official methods are followed.

The third type of oven is the forced-draft type in which the air is circulated rapidly over the heating elements and through the oven by means of a motor-driven fan. Temperature differences within this oven are very small. It has a high capacity in terms of moisture removal and is commonly used in large laboratories where many samples must be analyzed daily.

The conditions of drying the cheese sample depend upon the oven and the place and manner in which it is operated.

Temperatures vary somewhat in different parts of some ovens. Altitudes in different parts of the country affect the rate at which moisture is lost at any given temperature. The customary load of samples in the oven during the drying period and other factors associated with the routine of the laboratory affect the efficiency of the oven. In order to meet such variable and unpredictable conditions it is customary to advise the laboratory technician to dry the samples until they reach "constant" weight. Weight of a dried sample can be considered to be constant if it changes not more than 0.01 per cent of the weight of the original cheese in a period of one hour under approved drying conditions. The following drying routines with different ovens approximate "constant" weights in drying 5-gram samples of cheese with the types of drying dishes described in this discussion:

a) *High vacuum oven.* 100 C. (212°F.) for 5 hours at a vacuum of not less than 26 inches of mercury and with about 30 bubbles of air, dried in sulfuric acid, passing through the oven in one minute.

b) *Combination of convection and vacuum oven.* 105°C. (221°F.) for 16 hours with free circulation of air at atmospheric pressure followed by 1 hour at the same temperature under not less than 20 inches of vacuum.

c) *Forced draft.* 110°C. (230°F.) for 16 hours.

d) *Convection oven.* 110°C. (230°F.) for 24 hours.

**Procedure**

1. Dry the clean, moisture dishes and covers in the oven for 1 hour under the temperature and vacuum conditions to be used in drying the cheese. Place the dried dishes in the desiccator for 30 minutes or until they have cooled to room temperature.

2. Weigh a dish and cover and record the number and weight.

3. Place approximately the desired amount of cheese in the dish, replace the cover, and weigh as rapidly as possible. A 3- to 5-gram sample is adequate when the analytical balances are used; a 5- to 10-gram sample is suggested when the torsion balance is used. Record the exact weight of the cheese used.

4. Place the weighed dish of cheese in the drying oven. Adjust the cover by tilting it slightly to permit the escape of moisture vapor but not enough to permit loss of cheese by spattering.

5. Dry the cheese according to the method which has been recommended above for the type of oven to be used.

6. Remove the dish after the drying interval when the sample has come to constant weight and place it in the desiccator for about 1 hour or until the dish and its contents have come to room temperature.

7. Place the covered dish on the balances and weigh. The loss in weight during the drying interval represents the moisture content of the cheese. The loss of weight in grams, divided by the weight of the sample in grams, multiplied by 100, equals the per cent of moisture in the cheese.

## Quick Tests for Moisture

**Oil test.** Gould (1937) described a method of drying a sample of cheese in oil to make a rapid moisture test of the product. The origin of the test seems obscure although it was mentioned by Sammis (1917). Gould found that the addition of small amounts of common salt, sodium chloride, to the oil increased the accuracy of the procedure. This test gave results averaging approximately 0.5% higher than the Mojonnier test. Individual differences ranged from −0.09 to +1.29% in 20 observations. Later experiments by Gould (1938) showed the oil test giving values which averaged 0.1% less than those obtained by drying the cheese in a steam oven operating at 85 pounds pressure. Individual differences between samples dried by the oven and by the modified oil methods ranged from −0.71 to +0.96% in 17 observations.

Gould (1937) performed the oil test by placing 20 ml. of high grade olive oil and about 1 gram of common salt in an aluminum dish about 2 inches high and 3 inches in diameter. The dish and its contents were heated over a low gas flame until the oil fumed slightly. The dish and oil were cooled and weighed on a torsion balance. Five grams of finely chopped cheese was weighed into the dish and then dried by heating over a low gas flame. The dish and its contents were shaken gently during heating to keep the cheese from sticking to the dish and to permit more rapid evolution of moisture. Heating was continued for 5 to 7 minutes or until bubbling ceased, after which the dish and its contents were cooled and weighed to determine the amount of moisture lost.

This is good practical test where an approximation of the moisture content gives adequate information.

**Drying lamp.** A drying lamp is a special device made by leading manufacturers of electric light bulbs. It contains a built-in reflector and is commonly rated at 250 watts. This lamp can be used as a source of heat in making moisture tests. It is useful in drying samples of melted process cheese to check on the composition of the product during the actual processing operation. Many different conditions are used in drying cheese with the drying lamps. Specific directions can not be given at this time without the warning that the results should be carefully checked against a standard method of drying until the conditions established give satisfactory agreement. The conditions include: size and shape of dish, size of sample, kind of cheese, distance of lamp above sample, insulation beneath the dish, uniformity of current to the lamp, time allowed for preheating the lamp, protection of the lamp and dish from cooling air currents, and differences between individual lamps. Practically all of these factors can be controlled in setting up the test. Uncontrolled factors can be slightly compensated by a skillful operator who is accustomed to observing and associating the color of the drying cheese and the presence or absence of bubbles of steam in the dish with the degree of agreement with a standard moisture test.

The following conditions are suggested for the mechanical adjustments for drying natural Cheddar cheese: aluminum dish about 2 inches high and 3 inches in diameter; a 5-gram sample; 2 inches from the low point of the bulb to the bottom of the dish (there will be slight clearance over the edge of the dish because the bulb is curved); an asbestos mat beneath the dish; 15 minutes preheating period for the lamp; and an 18 minute drying period.

The procedure to be followed in making the test with the drying lamp is identical to that described on page 464 with the exception that the dish should not be covered during the 18 minute period when it is exposed to the drying lamp. The drying period of 18 minutes is an approximation of the time required to attain "constant" weight. The results should be checked against a standard test. The dried sample may be cooled, weighed, reheated for 4 minutes and again cooled and weighed to check the completeness of drying. The sample may be regarded as "dry" if the weight lost in the 4 minute period does not exceed 0.05% of the weight of the original sample of cheese.

This is a practical test which can be used when an approximation within 0.5% of the actual moisture content of the cheese sample is considered to be a satisfactory estimate.

## Testing Cheese for Salt

Wilster, et al. (1937, 1940) recommended the following method for measuring the salt content of cheese:

### Reagents

*Silver nitrate.* Prepare a 0.1711 *N* solution by dissolving 29.06 grams of C.P. silver nitrate in water and diluting to 1000 ml.

*Nitric acid.* Use chemically pure, halogen-free nitric acid.

*Potassium permanganate.* Prepare a saturated solution.

*Ferric ammonium sulfate.* Prepare a saturated solution to be used as an indicator.

*Potassium* (or ammonium) *sulfocyanate.* Dissolve 16.63 grams of potassium sulfocyanate in distilled water and dilute to 1000 ml.

*Sodium chloride.* Dissolve 10 grams of chemically pure, dry salt in distilled water and dilute to 1000 ml.

### Procedure

1. Sample the cheese as directed on page 461 for testing for fat and moisture. Grind the sample to a smooth mixture.
2. Weigh accurately about 3 grams of ground cheese in a 300 ml. Erlenmeyer flask.
3. Add 10 ml. of 0.1711 *N* silver nitrate solution.
4. Add 15 ml. of nitric acid and 50 ml. of distilled water.
5. Heat the mixture to boiling.
6. Add approximately 15 ml. of the saturated potassium permanganate solution in three portions of 5 ml. each while the mixture is boiling. Continue boiling until the particles of cheese are completely dissolved.
7. Dilute the contents of the flask with 100 ml. of distilled water and decant the clear liquid into a clean beaker. Wash the precipitate by adding another 100 ml. volume of distilled water and decant again.
8. Add 3 ml. of the saturated ferric ammonium sulfate solution to the clear solution and titrate with the 0.1711 *N* potassium sulfocyanate.
9. Run a blank test on the reagents by following the same procedure, omitting the cheese, and adding sugar to destroy the excess permanganate.
10. Calculate the percentage of salt by subtracting the milliliters of potassium sulfocyanate used in the titration from 10,

the number of milliliters of silver nitrate used. Divide this difference by the grams of cheese used to get the percentage of salt in the cheese.

Overman and Whitmore (1939) described a method of measuring salt in cheese by digesting the cheese in a distilling flask with sulfuric acid, distilling off the hydrogen chloride, absorbing the hydrogen chloride in a known amount of silver nitrate and nitric acid solution, and titrating the excess silver nitrate with ammonium or potassium sulfocyanate.

Marquardt (1938) showed that it was possible to titrate solutions prepared from cheese less than 5 days old without digesting them.

Arbuckle (1946) studied the possibility of measuring salt content of fresh Cheddar cheese and Cottage cheese with the mercurimetric method. He dissolved the salt from fresh cheese by grinding it, dispersing 10 grams of it in 250 ml. of water and heating the mixture to 150° to 160°F. He titrated a 25 ml. aliquot of the clear solution with 0.1711 *N* mercuric nitrate using s-diphenylcarbazone as indicator. The procedure was accurate and showed a definite sharp end-point in the titration.

## CHEESE EXTRANEOUS MATTER TEST

Cheese is tested for extraneous matter by dissolving a known amount in a mild solvent, filtering the mixture, and collecting the undissolved material on a milk sediment disk for examination and grading.

This test is used to detect unsanitary conditions of milk production and cheese manufacture. It is used for demonstrating the necessity of correcting unsatisfactory practices. If the test is satisfactory it does not prove that the conditions of milk production or cheese manufacturing were satisfactory. In this respect it has the same limitations of interpretation as the milk sediment test.

It is the general practice to classify cheese extraneous matter tests into four grades, Good, Fair, Poor, and Illegal; these grades are numbered 1, 2, 3, and 4, respectively. The State of Illinois, Division of Foods and Dairies, 228 South Wabash Avenue, Chicago, Illinois, has printed photographs of Illinois standards which are widely accepted in the industry. The National Cheese Institute, Inc., 110 North Franklin Street, Chicago, Ill., has reproduced such standards.

**Cheese solvents.** Two cheese solvents have found common acceptance in the industry; they are sodium citrate and phosphoric acid. Other solvents are also used in food regulatory laboratories for special purposes. The use of sodium citrate solvent was first described by Spicer and Price (1938). They advocated its use with 100 grams of cheese. Modifications of this test that will be described in this section, are probably most widely used in industry.

The phosphoric acid solvent was first applied by Turner, Rogers, and Conquest (1942). They suggested its use with a 50-gram sample of cheese. This solvent is effective with a minimum of special equipment and the procedure for using it will be described. Both solvents have only a slight dissolving effect upon the common types of extraneous matter found in cheese (Miersch and Price, 1944).

**Sampling cheese for extraneous matter tests.** Miersch and Price (1944) found that extraneous matter was distributed fairly uniformly in a single cheese but was variable from cheese to cheese in the vat lot. They recommended sampling more than one cheese in each lot but recognized the economic difficulty of the practice. They further recommended the taking of samples at regular and frequent intervals to judge the operation conditions of a factory.

Size of sample has been of great concern. The one-half pound (227-gram) sample is favored by large handlers of cheese because it is good for demonstration as well as inspection purposes. The 50-gram sample filtered on poplin is about half as effective as the 227-gram sample in detecting critical material when 20 per cent of the samples are defective. This fact is of particular interest in considering the merits of the 15-gram sample used in the test devised by Thibodeau (1946). He proposed to reduce the filtering surface in proportion to the reduction in size of sample from 227 grams. Hood (1948) agreed with Thibodeau that the small sample was an effective and practical means of making routine tests.

Obtaining a sample for analysis is done in three ways: 1) plugs may be drawn from the cheese with a large trier; 2) a V-shaped wedge may be cut from one end of a cheese; or 3) curd may be taken from the vat at the time of pressing. The V-shaped sample of cheese is removed with a special knife, designed by Bohacek and Swanson (Erekson, 1946); when this sample is taken, the cut surfaces of the cheese can be covered effectively by paraffining the cheese.

### Apparatus and reagents for sodium citrate solvent

Complete apparatus and supplies for the extraneous matter test are distributed by Triple E Supplies, Plymouth, Wisconsin. They can be assembled from dairy supply companies and scientific apparatus and chemical supply organizations. Materials needed are:

1. Sampling device such as a cheese trier or V-shaped knife.

2. Food grater for a few samples, or a Waring Blendor for many samples.

3. Scales and weights.

4. Two-liter white enamel measuring graduate or stainless steel containers; one may be adequate for a few samples.

5. Hot plate for a few samples, or water bath with heater for many samples.

6. Mechanical stirrer and support. A kitchen mixer will do the work on the small scale. Several units are desirable for many samples.

7. Hand-operated pressure or vacuum sediment tester for a few tests, or the Erekson Filter with water pump and suction tubing for many tests.

8. Thermometer, wash bottle, 5-gallon bottles for filtered sodium citrate solution.

9. Ten per cent solution of sodium citrate made by dissolving 100 grams in 900 ml. of distilled water and filtering the solution.

10. Milk sediment disks, 1.25 inches in diameter; sediment disk envelopes and cards for mounting disks; moisture-proof bags for holding cheese samples for analysis; parchment paper for grated samples.

11. Standards for grading cheese sediment disks such as those of the State of Illinois, Division of Foods and Dairies, 228 South Wabash Avenue, Chicago, Illinois.

12. A low-power microscope, 30× to 100× magnification, for identifying critical extraneous material.

### Procedure for the sodium citrate solvent

1. Grate the cheese on a clean surface, such as parchment paper or a metal tray.

2. Weigh 227 grams (8 ounces) of the shredded cheese and place it in the 2-liter measuring graduate or stainless steel containers.

3. Add 850 ml. of filtered, 10 per cent, sodium citrate solution.

Hood and Sproule, (1944) recommended weighing the sample without grating; placing the sample in a Waring Blendor with 500 ml. of sodium citrate solution at 113° F.; stirring for 30 seconds or until the mixture was homogeneous; emptying the Blendor into the 2-liter graduate; and rinsing the Blendor twice with additional 250 and 100 ml. portions of citrate. These rinsings were added to the cheese dispersion in the 2-liter graduate. This treatment shortens the time required for the test.

4. Place the container in the water bath or on the hot plate, insert the mechanical agitator, and warm to 140° to 150°F. The sample is usually completely dissolved in 45 minutes. The time can be reduced by soaking the cheese for a few hours or even overnight. The Hood and Sproule method requires only 20 minutes for heating and stirring to a maximum temperature of 150° to 160°F. This temperature exceeds the recommendations of Spicer and Price (1938) who observed that at temperatures above 140°F. protein materials sometimes coagulated to produce a slime which clogged the filter pad.

The cheese must be entirely dissolved before proceeding with the test.

5. Lift up the agitator, hold it over the cheese solution, and rinse it with distilled water to return all sediment to the test solution.

6. Adjust the milk sediment disk in the sediment tester with the compact or "waffle" side up.

7. Pour the cheese solution into the tester. Rinse the emptied container with distilled water and add the rinsings to the sediment tester.

8. Pump the solution through the sediment tester. Rinse the sides of the tester with distilled water and filter these rinsings so that all particles of sediment will be on the disk.

9. Remove the disk; dry it at a low temperature in a place protected from dust; place the dried disk in a transparent envelope; and mount the disk on a card with suitable marks for identification.

10. Classify the test disk by visual inspection. Examine it under the microscope for critical material.

### Interpretation

A clean sediment test disk is not proof that the sanitary condition of the milk supply and the factory are entirely satisfactory.

An unsatisfactory sediment disk by visual inspection is indi cative of unsanitary or careless conditions of milk production or cheese manufacture, or both.

A disk which is clean to the naked eye may contain particles of soil and vegetable matter that are visible under the microscope. Microscopic examination of the disk is necessary to detect rodent hairs, insect fragments, and the like. Such contamination must be regarded as evidence of unsatisfactory farm or factory conditions, or both.

Microscopic examination of extraneous material on the sediment disk may indicate the source of contamination; soil, for example, usually gets into the milk before it reaches the factory; coal dust is usually evidence of contamination in the factory.

### Precautions

Avoid contamination of the sample or test while taking the sample, transporting it to the laboratory, and making the test. Tobacco ashes, dust, and dirt from unclean surfaces or utensils may spoil the test. Equipment must be scrupulously clean. The test solution should be exposed as little as possible at all stages of handling.

## THE PHOSPHORIC ACID TEST FOR EXTRANEOUS MATTER IN CHEESE

This test was devised by Turner, Rogers, and Conquest (1942). The acid is more active chemically than the citrate. It will attack a poorly tinned or copper sediment tester and render the test worthless. It is very useful when special agitators are not available.

### Apparatus and Supplies for phosphoric acid solvent

Apparatus and supplies needed for the phosphoric acid test are: a trier or other sampling device; scales and weights; food grater, preferably the scraping type; 1-liter beakers; 500 ml. measuring graduate, glass or enamel; glass stirring rods; thermometer; wash bottle; pressure or vacuum, milk sediment tester; hot plate or gas burner; milk sediment disks, 1.25 inches in diameter; transparent envelopes and cards for mounting disks; standards for grading sediment disks; low power microscope (30× to 100× magnification) for examining disks.

### Reagents

Distilled water and a solution of phosphoric acid are needed. The phosphoric acid ($H_3PO_4$) solution is made by mixing phos phoric acid (specific gravity 1.710), 85 per cent, with distilled water at the rate of 7 ml. of acid to 1 liter of water.

**Procedure using the phosphoric acid solvent**

1. Sample the cheese with the trier and place it in a clean container until analyzed.

2. Exclude the rind and grate the sample on a clean surface such as a parchment paper or metal tray.

3. Weigh 50 grams of grated cheese into a clean 1-liter beaker and add 500 ml. of previously filtered phosphoric acid solution.

4. Heat the mixture to the boiling point and boil gently for 10 minutes. Stir the mixture occasionally to prevent the cheese from sticking to the bottom of the beaker. The cheese must be dissolved before proceeding with the test.

5. Filter the hot solution through a milk sediment disk that has been placed in the tester with the compact or "waffle" side up. Rinse the stirring rod and beaker with distilled water and run the rinsings through the filter.

6. Remove the filter disk; dry it at low temperature in a dust-free atmosphere; place it in a transparent envelope; and mount it on a card with suitable identifying marks.

7. Examine the disk under the microscope to detect critical material. No published standards are available to classify the disks according to quantity of sediment retained. Miersch and Price (1944) found that a 1.25 inch disk of poplin used over the milk sediment disk in the tester was more effective in revealing sediment which might otherwise be hidden in the loose fibers of the ordinary sediment disk. They recommended it particularly for use with the phosphoric acid solvent.

## ACIDITY MEASUREMENTS

### Test for Titratable Acidity

Fresh milk contains various substances which neutralize alkali, such as: casein, albumin, phosphates, citrates and even carbon dioxide which is usually dissolved in milk. The amounts of these substances in milk are subject to wide variations. The titratable acidity of fresh milk is measured by determining the amount of alkali of known strength, usually 0.1 normal (N/10) sodium hydroxide, that is required to neutralize these milk constituents. A few drops of phenolphthalein is used to indicate when this neutralization has been accomplished. Phenolphthalein is colorless in acid and neutral solutions but turns red in a slightly alkaline solution. The first faint appearance of this red color in the test for acidity indicates that the alkali has combined with all of the acid-like constituents in the milk.

For the sake of convenience, the amount of alkali used to neutralize a given sample of milk is reported as its equivalent of lactic acid. One milliliter of N/10 sodium hydroxide will neutralize 0.009 grams of lactic acid. Actually, of course, if the milk is fresh it contains no lactic acid. The titratable acidity of fresh milk only indicates the presence of the normal milk constituents which combine with sodium hydroxide.

Knowledge of this combination of alkali with the milk constituents is essential to an understanding of the variations in the test for titratable acidity in milk and its products. The titratable acidity of fresh milk, or whey from fresh milk which has been coagulated by rennet, increases with the amount of dry matter in the milk or whey. When the lactose ferments under the action of acid-forming organisms, the acidity of the milk increases. It is this *increase* in acidity that indicates the presence and activity of these bacteria.

The titration test for acidity is applied to milk, whey, skim milk, and other liquid dairy products.

**Procedure**

1. Use a Babcock 17.6 ml. pipette to measure the liquid to be titrated; place the measured liquid in a white cup.

2. Add 1 ml. of indicator solution made by dissolving 1 gram of phenolphthalein in 100 ml. of alcohol.

3. Add N/10 sodium hydroxide drop by drop from a burette with smallest divisions of 0.1 ml. When the addition of 1 drop of alkali causes the appearance of a faint pink color, this is the "neutral" point. Stir the mixture constantly with a glass rod while the alkali is being added.

4. Divide the number of milliliters of alkali used by 20 to calculate the percentage of "lactic acid" in the 17.6 ml. sample.

An 8.8 ml. sample may be used in making this test. The test is performed in the manner described in steps 1, 2, and 3, except that 0.5 ml. of phenolphthalein solution is added for indicator. The percentage of "lactic acid" is calculated by dividing by 10 the milliliters of alkali used in neutralizing the sample.

## HOT IRON TEST FOR ACIDITY IN CURD

This is a practical factory test to ascertain the acidity of the Cheddar cheese curd before dipping and milling. The developing acid acts upon the protein of the curd to form mono-calcium paracaseinate which forms silky threads under the conditions of the hot iron test. The threads increase in length as the acidity of the curd increases.

### Apparatus

A clean, smooth piece of iron, like a piece of pipe, or spring steel is used in making the test. An electric hot plate with a smooth steel surface may serve as both iron and source of heat. A gas flame is a desirable source of heat when it is available. The iron may be heated in the firebox of the boiler.

### Procedure

1. When the curd is in the whey, remove about 1 ounce of it for the sample. Squeeze out the free whey and press the granules of curd together into a firm, cylindrically shaped mass. Dry the surface of this piece of curd in clean bandage or paper towel so that it is smooth, solid, and without loose particles or drops of whey.

2. Rest the heated part of the hot iron on a brick or flat, fireproof surface and hold it steady with one hand. Hold the curd in the fingers of the other hand with the palm of the hand facing the iron. Steady this hand on the same surface on which the iron rests so that the curd is held approximately one-half inch away from the iron.

3. Touch the tip of the cylindrical piece of curd lightly to the iron to find a spot to which the curd will stick without burning; this temperature approximates 250°F.

4. Press lightly against the iron with a smooth surface of the curd that has not previously touched the iron; slide it gently along the iron for about one quarter of an inch, and slowly draw the curd away. These motions are performed entirely with the fingers; the whole hand is steadied on its support in almost the same position as that used in writing.

5. Observe the length of the hair-like threads at their breaking point; report the results as "inches" on the hot iron.

6. Discard the piece of curd and brush or rub all particles of curd from the iron so that it will be clean and smooth for the next test.

Samples of curd for testing during the cheddaring operation are cut from the blocks with a sharp knife. Excess moisture is removed from the curd with a dry piece of bandage or paper towel. The curd is then touched to the iron in the manner which has already been described.

## Measurement of pH with the Quinhydrone Electrode

The quinhydrone electrode provides a convenient and accurate method for measuring acidity of milk, whey, curd, and cheese during curd making and cheese ripening. The measurements are reported in units of pH. Units of pH decrease as acidity increases. For example: normal fresh milk has a pH approximating 6.5 to 6.8, but a lactic starter, when it is ready to use, has a pH of 4.6. Table 15:1 shows comparable measurements of pH and titratable acidity during making and ripening of several lots of Cheddar cheese.

Measurements of pH are particularly valuable because acidity is so closely related to the physical and chemical properties of milk, curd, and cheese. Brown and Price (1934) studied the application of pH measurements in the making of Cheddar cheese. They found that such measurements were very useful for controlling manufacturing operations. They pointed out that pH values approximating 5.1 were normal in Cheddar cheese when three days old; lower pH values at that age were associated with acid defects.

Measurements of acidity in dairy products are commonly made with the glass electrode and the quinhydrone electrode; other methods can be used. Although the glass electrode is very convenient to use with liquids, it is not so well adapted for use with curd and cheese. The quinhydrone electrode, which can be used for milk, whey, curd, and cheese, is commonly used in cheese laboratories and in a few factories.

### Apparatus and reagents

Apparatus and reagents for pH measurements can be obtained from scientific apparatus and chemical supply companies. Essentials for using the quinhydrone procedure are:

1. A *potentiometer* with a range of readings from 0 to 1 volt with smallest graduations of 0.001 volts.

2. *Calomel half-cell* made with saturated potassium chloride; such apparatus was described by Sanders (1938); a modification by Sommer is illustrated in figure 28:1.

3. *Quinhydrone electrode* like that described by Watson (1927), Sanders (1938), or Sommer's modification which is shown in figure 28:1. Sommer's electrode consists of about 10 cm. of 20 gage copper wire fused to a 2 cm. length of platinum wire which in turn is fused to a 2 to 3 cm. piece of 21 gage gold wire. The joined wires are contained in a 4 mm. soft glass tube about 8 to 10 cm. long. One end of the tube is sealed around the platinum wire as close as possible to the point of its fusion with the gold wire. The other end of the tube is closed with a brass terminal connection into which the copper wire is soldered. The terminal connection is sealed into the tube with laboratory cement.

A syringe-like device to hold the liquid to be tested is a desirable convenience which is shown in figure 28:1. The barrel of the syringe is formed by a glass tube slightly shorter than the electrode and large enough in diameter to hold the electrode tube. The upper end of the barrel is closed with a rubber sleeve through which the electrode tube slides to form the piston. The lower end of the tube is drawn out like the tip of a pipette. The liquid to be tested can be pulled up into the syringe by a pump-like action of the electrode. The gold wire remains bathed in the liquid when the device is working properly.

4. Saturated solution of potassium chloride in distilled water; this solution should always contain undissolved crystals of the salt.

5. Crystals of quinhydrone.

6. Mortar and pestle, small beakers or test tubes, glass tubes about three inches long and large enough in diameter to insert the gold end of the quinhydrone electrode.

7. Buffer solutions for checking working accuracy in the range of approximately 4 to 7.0 pH.

### Procedure for measuring pH of liquids

1. Balance the standard cell in the potentiometer against its working battery according to instructions furnished with each machine by the manufacturer.

2. Connect the calomel half-cell with a battery clip and insulated copper wire to the "—" post of the potentiometer. When Sommer's apparatus is used, draw saturated potassium chloride from reservoir (R) through stopcocks (A) and (B) into the shallow beaker (W). Close stopcock (A) when the tip of the side arm is covered with the potassium chloride solution and when the side arm is free of bubbles of air.

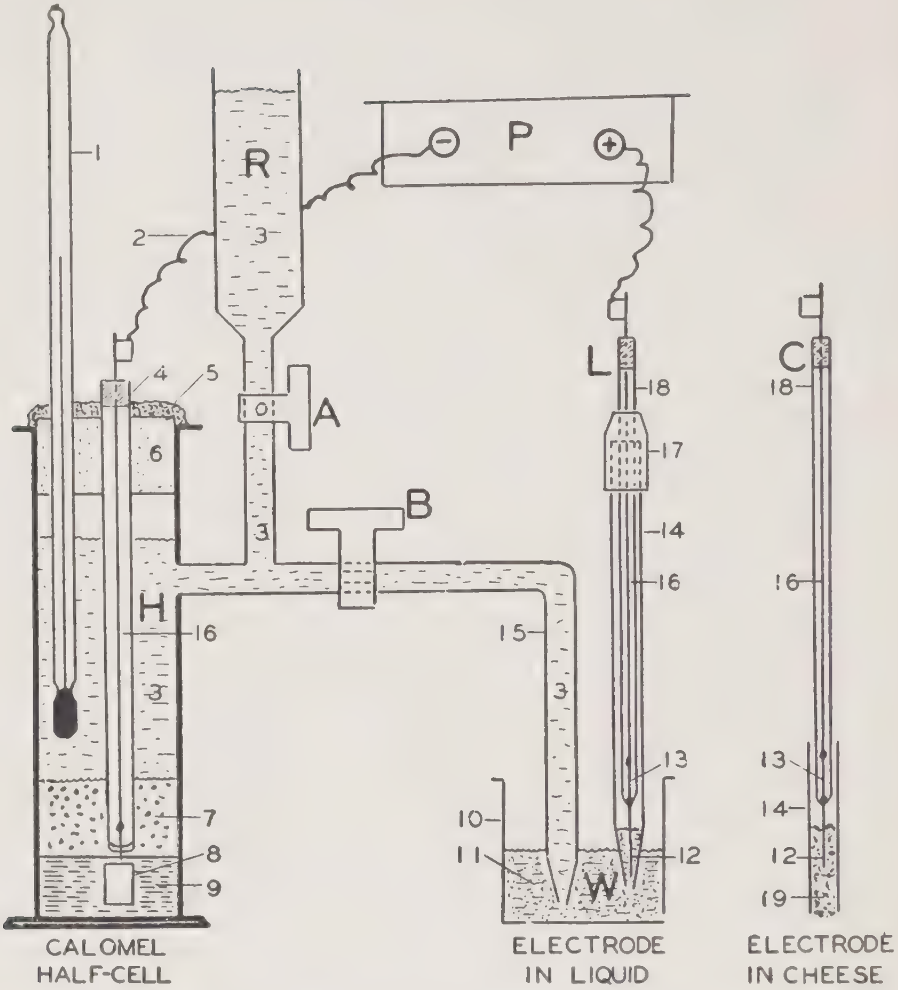

P
R
A
B
L
C
H
W
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
CALOMEL HALF-CELL
ELECTRODE IN LIQUID
ELECTRODE IN CHEESE

Figure 28:1. Apparatus for measuring pH of dairy products.

*Key to identifying letters*

A —stopcock
B —stopcock
C —electrode assembly for cheese and curd
H —calomel half-cell
L —electrode assembly for liquids
P —potentiometer
R —reservoir for saturated potassium chloride
W—beaker for holding (a) liquid to be tested, or (b) saturated potassium chloride
1—thermometer
2—wire to potentiometer
3—saturated potassium chloride
4—terminal of half-cell
5—sealing compound
6—rubber stopper
7—calomel
8—platinum foil
9—mercury
10—beaker
11—may be liquid with quinhydrone, or may be saturated potassium chloride
12—gold wire
13—platinum wire
14—glass tubing
15—side arm from calomel half-cell
16—copper wire
17—rubber sleeve
18—glass tubing
19—cheese paste mixed with quinhydrone

3. Wash the gold wire of the electrode (L) with a soft brush and hot water, or boil it in water for a few minutes to clean it and to remove impurities which might interfere with the measurement.

4. Place about 5 to 10 ml. of the liquid to be tested in a small beaker or test tube. The liquid should be at the same temperature as the calomel half-cell although small differences are of no practical significance. Mix with it a small portion of quinhydrone crystals. The amount necessary for this quantity of liquid can be lifted with the pointed end of a pen-knife.

5. Use syringe (L) in figure 28:1 and pull up into it enough of the liquid and quinhydrone mixture to bathe the end of the gold wire.

6. Place the tip of syringe (L) in the beaker of potassium chloride solution (W) and connect the terminal of the electrode with the "+" post of the potentiometer as shown in figure 28:1.

7. Balance the galvanometer of the potentiometer with the graduated dials so that it shows no deflection when the switch is closed momentarily. It is important to achieve this balance by closing the galvanometer switch for intervals of less than one second. Necessary adjustments of the graduated dials are made only when the galvanometer switch is open.

8. Add the voltage values on the dial switch and the continuously adjustable dial and note the exact temperature of the half-cell.

9. Convert the voltage reading to pH by referring to table 28:1. The use of this table can be illustrated by an example. Assume that a sample of milk shows a voltage reading of 0.069 with the temperature of the calomel half-cell at 22°C. Turn to the section of the table headed "22 C." In the first column, under "Volts" read down to —0.060; follow that line to the right to the square in the column headed ".009"; the desired pH value is in that square, 6.56. For further comments on the use of table 28:1, see item 6 under "Precautions" on page 486.

10. Wash the electrode with hot water and a soft brush. Flush potassium chloride from reservoir (R) through the side arm to prevent diffusion of samples or quinhydrone into the calomel half-cell.

### Procedure for measuring pH of curd or cheese

1. Proceed as in steps 1 through 3 in making pH measurements of liquids.

2. Grind about 5 grams of cheese or curd with mortar and

pestle until it is practically smooth and homogeneous. (If the curd is too soft to make a semi-solid paste, complete the measurement as for a liquid.) Add enough quinhydrone to color the mixture grey and mix quickly with the cheese.

3. Take a three-inch length of glass tubing and tamp it firmly into the cheese paste in the mortar until the tube is half-full of the paste.

4. Press the gold wire of the electrode (C) into—but not through—the cheese in the tube; hold the end of the tube against the bottom of the mortar so the cheese will not be pushed out of the tube.

5. Place the cheese end of the tube into the small beaker of saturated solution of potassium chloride, (W) in figure 28:1, and connect the terminal of the electrode with the "+" post of the potentiometer.

6. Complete the balancing of the galvanometer, the reading of the voltage, conversion of voltage to pH, and cleaning of the equipment as described in making pH measurements of liquids, steps 7 through 10.

### Precautions

1. Test the apparatus and reagents by measuring the pH of a standard buffer solution of a known pH. Use the same procedure described for measuring the pH of a liquid, but substitute the buffer solution for the unknown sample.

2. Have the temperature of the sample and that of the calomel half-cell as nearly alike as possible.

3. Readings should be made in less than 5 minutes after the quinhydrone crystals have been added to the sample. Samples of cheese which turn pink before the reading is made should be discarded and other measurements made more quickly.

4. When there is drifting of the potential so that there is difficulty in getting the galvanometer properly adjusted, discard the sample and start again. The trouble is usually an improperly cleaned electrode, or too much time elapsing between the adding of the quinhydrone crystals and the balancing of the potentiometer. To clean the electrode, wash it in hot water or immerse it for several minutes in boiling water. When it is not in use, keep the gold-wire end of the electrode in distilled water to which a small portion of quinhydrone may be added. Keep several electrodes on hand for replacements. Measurements with all electrodes should agree within ± 0.02 pH.

### TABLE 28:1. CONVERTING VOLTAGE TO pH FOR MEASUREMENTS MADE WITH THE QUINHYDRONE ELECTRODE AND THE SATURATED CALOMEL HALF-CELL AT 20° TO 30°C.

20°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.040 | 7.12 | 7.10 | 7.09 | 7.07 | 7.05 | 7.03 | 7.02 | 7.00 | 6.98 | 6.97 |
| —.050 | 6.95 | 6.93 | 6.91 | 6.90 | 6.88 | 6.86 | 6.85 | 6.83 | 6.81 | 6.79 |
| —.060 | 6.78 | 6.76 | 6.74 | 6.72 | 6.71 | 6.69 | 6.67 | 6.66 | 6.64 | 6.62 |
| —.070 | 6.60 | 6.59 | 6.57 | 6.55 | 6.54 | 6.52 | 6.50 | 6.48 | 6.47 | 6.45 |
| —.080 | 6.43 | 6.41 | 6.40 | 6.38 | 6.36 | 6.35 | 6.33 | 6.31 | 6.29 | 6.28 |
| —.090 | 6.26 | 6.24 | 6.23 | 6.21 | 6.19 | 6.17 | 6.16 | 6.14 | 6.12 | 6.10 |
| —.100 | 6.09 | 6.07 | 6.05 | 6.04 | 6.02 | 6.00 | 5.98 | 5.97 | 5.95 | 5.93 |
| —.110 | 5.92 | 5.90 | 5.88 | 5.86 | 5.85 | 5.83 | 5.81 | 5.80 | 5.78 | 5.76 |
| —.120 | 5.74 | 5.73 | 5.71 | 5.69 | 5.67 | 5.66 | 5.64 | 5.62 | 5.61 | 5.59 |
| —.130 | 5.57 | 5.55 | 5.54 | 5.52 | 5.50 | 5.49 | 5.47 | 5.45 | 5.43 | 5.42 |
| —.140 | 5.40 | 5.38 | 5.36 | 5.35 | 5.33 | 5.31 | 5.30 | 5.28 | 5.26 | 5.24 |
| —.150 | 5.23 | 5.21 | 5.19 | 5.18 | 5.16 | 5.14 | 5.12 | 5.10 | 5.09 | 5.07 |
| —.160 | 5.06 | 5.04 | 5.02 | 5.00 | 4.99 | 4.97 | 4.95 | 4.93 | 4.92 | 4.90 |
| —.170 | 4.88 | 4.87 | 4.85 | 4.83 | 4.81 | 4.80 | 4.78 | 4.76 | 4.75 | 4.73 |
| —.180 | 4.71 | 4.69 | 4.68 | 4.66 | 4.64 | 4.62 | 4.61 | 4.59 | 4.57 | 4.56 |
| —.190 | 4.54 | 4.52 | 4.50 | 4.49 | 4.47 | 4.45 | 4.44 | 4.42 | 4.40 | 4.38 |
| —.200 | 4.37 | 4.35 | 4.33 | 4.31 | 4.30 | 4.28 | 4.26 | 4.25 | 4.23 | 4.21 |
| —.210 | 4.20 | 4.18 | 4.16 | 4.14 | 4.13 | 4.11 | 4.09 | 4.08 | 4.06 | 4.04 |
| —.220 | 4.02 | 4.01 | 3.99 | 3.97 | 3.96 | 3.94 | 3.92 | 3.90 | 3.89 | 3.87 |

21°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.040 | 7.09 | 7.07 | 7.05 | 7.03 | 7.02 | 7.00 | 6.98 | 6.97 | 6.95 | 6.93 |
| —.050 | 6.91 | 6.90 | 6.88 | 6.86 | 6.85 | 6.83 | 6.81 | 6.79 | 6.78 | 6.76 |
| —.060 | 6.74 | 6.73 | 6.71 | 6.69 | 6.67 | 6.66 | 6.64 | 6.62 | 6.61 | 6.59 |
| —.070 | 6.57 | 6.55 | 6.54 | 6.52 | 6.50 | 6.49 | 6.47 | 6.45 | 6.43 | 6.42 |
| —.080 | 6.40 | 6.38 | 6.37 | 6.35 | 6.33 | 6.31 | 6.30 | 6.28 | 6.26 | 6.25 |
| —.090 | 6.23 | 6.21 | 6.19 | 6.18 | 6.16 | 6.14 | 6.13 | 6.11 | 6.09 | 6.07 |
| —.100 | 6.06 | 6.04 | 6.02 | 6.01 | 5.99 | 5.97 | 5.95 | 5.94 | 5.92 | 5.90 |
| —.110 | 5.89 | 5.87 | 5.85 | 5.83 | 5.82 | 5.80 | 5.78 | 5.77 | 5.75 | 5.73 |
| —.120 | 5.71 | 5.70 | 5.68 | 5.66 | 5.65 | 5.63 | 5.61 | 5.59 | 5.58 | 5.56 |
| —.130 | 5.54 | 5.53 | 5.51 | 5.49 | 5.47 | 5.46 | 5.44 | 5.42 | 5.41 | 5.39 |
| —.140 | 5.37 | 5.35 | 5.34 | 5.32 | 5.30 | 5.29 | 5.27 | 5.25 | 5.23 | 5.22 |
| —.150 | 5.20 | 5.18 | 5.17 | 5.15 | 5.13 | 5.11 | 5.10 | 5.08 | 5.06 | 5.05 |
| —.160 | 5.03 | 5.01 | 4.99 | 4.98 | 4.96 | 4.94 | 4.93 | 4.91 | 4.89 | 4.87 |
| —.170 | 4.86 | 4.84 | 4.82 | 4.81 | 4.79 | 4.77 | 4.75 | 4.74 | 4.72 | 4.70 |
| —.180 | 4.69 | 4.67 | 4.65 | 4.63 | 4.62 | 4.60 | 4.58 | 4.57 | 4.55 | 4.53 |
| —.190 | 4.51 | 4.50 | 4.48 | 4.46 | 4.45 | 4.43 | 4.41 | 4.39 | 4.38 | 4.36 |
| —.200 | 4.34 | 4.33 | 4.31 | 4.29 | 4.27 | 4.26 | 4.24 | 4.22 | 4.21 | 4.19 |
| —.210 | 4.17 | 4.15 | 4.14 | 4.12 | 4.10 | 4.09 | 4.07 | 4.05 | 4.03 | 4.02 |
| —.220 | 4.00 | 3.98 | 3.97 | 3.95 | 3.93 | 3.91 | 3.90 | 3.88 | 3.86 | 3.85 |

22°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.040 | 7.05 | 7.03 | 7.02 | 7.00 | 6.98 | 6.97 | 6.95 | 6.93 | 6.91 | 6.90 |
| —.050 | 6.88 | 6.86 | 6.85 | 6.83 | 6.81 | 6.80 | 6.78 | 6.76 | 6.74 | 6.73 |
| —.060 | 6.71 | 6.69 | 6.68 | 6.66 | 6.64 | 6.62 | 6.61 | 6.59 | 6.57 | 6.56 |
| —.070 | 6.54 | 6.52 | 6.50 | 6.49 | 6.47 | 6.45 | 6.44 | 6.42 | 6.40 | 6.39 |
| —.080 | 6.37 | 6.35 | 6.33 | 6.32 | 6.30 | 6.28 | 6.27 | 6.25 | 6.23 | 6.21 |
| —.090 | 6.20 | 6.18 | 6.16 | 6.15 | 6.13 | 6.11 | 6.09 | 6.08 | 6.06 | 6.04 |
| —.100 | 6.03 | 6.01 | 5.99 | 5.98 | 5.96 | 5.94 | 5.92 | 5.91 | 5.89 | 5.87 |
| —.110 | 5.86 | 5.84 | 5.82 | 5.80 | 5.79 | 5.77 | 5.75 | 5.74 | 5.72 | 5.70 |
| —.120 | 5.68 | 5.67 | 5.65 | 5.63 | 5.62 | 5.60 | 5.58 | 5.57 | 5.55 | 5.53 |
| —.130 | 5.51 | 5.50 | 5.48 | 5.46 | 5.45 | 5.43 | 5.41 | 5.39 | 5.38 | 5.36 |
| —.140 | 5.34 | 5.33 | 5.31 | 5.29 | 5.27 | 5.26 | 5.24 | 5.22 | 5.21 | 5.19 |
| —.150 | 5.17 | 5.16 | 5.14 | 5.12 | 5.10 | 5.09 | 5.07 | 5.05 | 5.04 | 5.02 |
| —.160 | 5.00 | 4.98 | 4.97 | 4.95 | 4.93 | 4.92 | 4.90 | 4.88 | 4.86 | 4.85 |
| —.170 | 4.83 | 4.81 | 4.80 | 4.78 | 4.76 | 4.75 | 4.73 | 4.71 | 4.69 | 4.68 |
| —.180 | 4.66 | 4.64 | 4.63 | 4.61 | 4.59 | 4.57 | 4.56 | 4.54 | 4.52 | 4.51 |
| —.190 | 4.49 | 4.47 | 4.45 | 4.44 | 4.42 | 4.40 | 4.39 | 4.37 | 4.35 | 4.34 |
| —.200 | 4.32 | 4.30 | 4.28 | 4.27 | 4.25 | 4.23 | 4.22 | 4.20 | 4.18 | 4.16 |
| —.210 | 4.15 | 4.13 | 4.11 | 4.10 | 4.08 | 4.06 | 4.05 | 4.03 | 4.01 | 3.99 |
| —.220 | 3.98 | 3.96 | 3.94 | 3.93 | 3.91 | 3.89 | 3.88 | 3.86 | 3.84 | 3.82 |

23°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.040 | 7.03 | 7.02 | 7.00 | 6.98 | 6.97 | 6.95 | 6.93 | 6.92 | 6.90 | 6.88 |
| —.050 | 6.86 | 6.85 | 6.83 | 6.81 | 6.80 | 6.78 | 6.76 | 6.75 | 6.73 | 6.71 |
| —.060 | 6.69 | 6.68 | 6.66 | 6.64 | 6.63 | 6.61 | 6.59 | 6.58 | 6.56 | 6.54 |
| —.070 | 6.52 | 6.51 | 6.49 | 6.47 | 6.46 | 6.44 | 6.42 | 6.41 | 6.39 | 6.37 |
| —.080 | 6.35 | 6.34 | 6.32 | 6.30 | 6.29 | 6.27 | 6.25 | 6.24 | 6.22 | 6.20 |
| —.090 | 6.18 | 6.17 | 6.15 | 6.13 | 6.12 | 6.10 | 6.08 | 6.07 | 6.05 | 6.03 |
| —.100 | 6.01 | 6.00 | 5.98 | 5.96 | 5.95 | 5.93 | 5.91 | 5.90 | 5.88 | 5.86 |
| —.110 | 5.85 | 5.83 | 5.81 | 5.79 | 5.78 | 5.76 | 5.74 | 5.73 | 5.71 | 5.69 |
| —.120 | 5.68 | 5.66 | 5.64 | 5.62 | 5.61 | 5.59 | 5.57 | 5.56 | 5.54 | 5.52 |
| —.130 | 5.51 | 5.49 | 5.47 | 5.45 | 5.44 | 5.42 | 5.40 | 5.39 | 5.37 | 5.35 |
| —.140 | 5.34 | 5.32 | 5.30 | 5.28 | 5.27 | 5.25 | 5.23 | 5.22 | 5.20 | 5.18 |
| —.150 | 5.17 | 5.15 | 5.13 | 5.11 | 5.10 | 5.08 | 5.06 | 5.05 | 5.03 | 5.01 |
| —.160 | 5.00 | 4.98 | 4.96 | 4.94 | 4.93 | 4.91 | 4.89 | 4.88 | 4.86 | 4.84 |
| —.170 | 4.83 | 4.81 | 4.79 | 4.78 | 4.76 | 4.74 | 4.72 | 4.71 | 4.69 | 4.67 |
| —.180 | 4.66 | 4.64 | 4.62 | 4.61 | 4.59 | 4.57 | 4.55 | 4.54 | 4.52 | 4.50 |
| —.190 | 4.49 | 4.47 | 4.45 | 4.44 | 4.42 | 4.40 | 4.38 | 4.37 | 4.35 | 4.33 |
| —.200 | 4.32 | 4.30 | 4.28 | 4.27 | 4.25 | 4.23 | 4.21 | 4.20 | 4.18 | 4.16 |
| —.210 | 4.15 | 4.13 | 4.11 | 4.10 | 4.08 | 4.06 | 4.04 | 4.03 | 4.01 | 3.99 |
| —.220 | 3.98 | 3.96 | 3.94 | 3.93 | 3.91 | 3.89 | 3.88 | 3.86 | 3.84 | 3.82 |

21°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.040 | 7.00 | 6.98 | 6.97 | 6.95 | 6.93 | 6.92 | 6.90 | 6.88 | 6.86 | 6.85 |
| —.050 | 6.83 | 6.81 | 6.80 | 6.78 | 6.76 | 6.75 | 6.73 | 6.71 | 6.69 | 6.68 |
| —.060 | 6.66 | 6.64 | 6.63 | 6.61 | 6.59 | 6.58 | 6.56 | 6.54 | 6.52 | 6.51 |
| —.070 | 6.49 | 6.47 | 6.46 | 6.44 | 6.42 | 6.41 | 6.39 | 6.37 | 6.36 | 6.34 |
| —.080 | 6.32 | 6.30 | 6.29 | 6.27 | 6.25 | 6.24 | 6.22 | 6.20 | 6.19 | 6.17 |
| —.090 | 6.15 | 6.13 | 6.12 | 6.10 | 6.08 | 6.07 | 6.05 | 6.03 | 6.01 | 6.00 |
| —.100 | 5.98 | 5.96 | 5.95 | 5.93 | 5.91 | 5.90 | 5.88 | 5.86 | 5.85 | 5.83 |
| —.110 | 5.81 | 5.80 | 5.78 | 5.76 | 5.74 | 5.73 | 5.71 | 5.69 | 5.68 | 5.66 |
| —.120 | 5.64 | 5.63 | 5.61 | 5.59 | 5.57 | 5.56 | 5.54 | 5.52 | 5.51 | 5.49 |
| —.130 | 5.47 | 5.46 | 5.44 | 5.42 | 5.41 | 5.39 | 5.37 | 5.35 | 5.34 | 5.32 |
| —.140 | 5.30 | 5.29 | 5.27 | 5.25 | 5.24 | 5.22 | 5.20 | 5.18 | 5.17 | 5.15 |
| —.150 | 5.13 | 5.12 | 5.10 | 5.08 | 5.07 | 5.05 | 5.03 | 5.01 | 5.00 | 4.98 |
| —.160 | 4.96 | 4.95 | 4.93 | 4.91 | 4.90 | 4.88 | 4.86 | 4.85 | 4.83 | 4.81 |
| —.170 | 4.79 | 4.78 | 4.76 | 4.74 | 4.73 | 4.71 | 4.69 | 4.68 | 4.66 | 4.64 |
| —.180 | 4.62 | 4.61 | 4.59 | 4.57 | 4.56 | 4.54 | 4.52 | 4.51 | 4.49 | 4.47 |
| —.190 | 4.45 | 4.44 | 4.42 | 4.40 | 4.39 | 4.37 | 4.35 | 4.34 | 4.32 | 4.30 |
| —.200 | 4.29 | 4.27 | 4.25 | 4.23 | 4.22 | 4.20 | 4.18 | 4.17 | 4.15 | 4.13 |
| —.210 | 4.12 | 4.10 | 4.08 | 4.06 | 4.05 | 4.03 | 4.01 | 4.00 | 3.98 | 3.96 |
| —.220 | 3.95 | 3.93 | 3.91 | 3.89 | 3.88 | 3.86 | 3.84 | 3.83 | 3.81 | 3.79 |

25°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.040 | 6.98 | 6.97 | 6.95 | 6.93 | 6.92 | 6.90 | 6.88 | 6.86 | 6.85 | 6.83 |
| —.050 | 6.81 | 6.80 | 6.78 | 6.76 | 6.75 | 6.73 | 6.71 | 6.70 | 6.68 | 6.66 |
| —.060 | 6.64 | 6.63 | 6.61 | 6.59 | 6.58 | 6.56 | 6.54 | 6.53 | 6.51 | 6.49 |
| —.070 | 6.48 | 6.46 | 6.44 | 6.43 | 6.41 | 6.39 | 6.37 | 6.36 | 6.34 | 6.32 |
| —.080 | 6.31 | 6.29 | 6.27 | 6.26 | 6.24 | 6.22 | 6.21 | 6.19 | 6.17 | 6.15 |
| —.090 | 6.14 | 6.12 | 6.10 | 6.09 | 6.07 | 6.05 | 6.04 | 6.02 | 6.00 | 5.99 |
| —.100 | 5.97 | 5.95 | 5.93 | 5.92 | 5.90 | 5.88 | 5.87 | 5.85 | 5.83 | 5.82 |
| —.110 | 5.80 | 5.78 | 5.77 | 5.75 | 5.73 | 5.71 | 5.70 | 5.68 | 5.66 | 5.65 |
| —.120 | 5.63 | 5.61 | 5.60 | 5.58 | 5.56 | 5.55 | 5.53 | 5.51 | 5.49 | 5.48 |
| —.130 | 5.46 | 5.44 | 5.43 | 5.41 | 5.39 | 5.38 | 5.36 | 5.34 | 5.33 | 5.31 |
| —.140 | 5.29 | 5.28 | 5.26 | 5.24 | 5.22 | 5.21 | 5.19 | 5.17 | 5.16 | 5.14 |
| —.150 | 5.12 | 5.11 | 5.09 | 5.07 | 5.06 | 5.04 | 5.02 | 5.00 | 4.99 | 4.97 |
| —.160 | 4.95 | 4.94 | 4.92 | 4.90 | 4.89 | 4.87 | 4.85 | 4.84 | 4.82 | 4.80 |
| —.170 | 4.78 | 4.77 | 4.75 | 4.73 | 4.72 | 4.70 | 4.68 | 4.67 | 4.65 | 4.63 |
| —.180 | 4.62 | 4.60 | 4.58 | 4.56 | 4.55 | 4.53 | 4.51 | 4.50 | 4.48 | 4.46 |
| —.190 | 4.45 | 4.43 | 4.41 | 4.40 | 4.38 | 4.36 | 4.35 | 4.33 | 4.31 | 4.29 |
| —.200 | 4.28 | 4.26 | 4.24 | 4.23 | 4.21 | 4.19 | 4.18 | 4.16 | 4.14 | 4.13 |
| —.210 | 4.11 | 4.09 | 4.07 | 4.06 | 4.04 | 4.02 | 4.01 | 3.99 | 3.97 | 3.96 |
| —.220 | 3.94 | 3.92 | 3.91 | 3.89 | 3.87 | 3.85 | 3.84 | 3.82 | 3.80 | 3.79 |

26°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.040 | 6.95 | 6.93 | 6.92 | 6.90 | 6.88 | 6.86 | 6.85 | 6.83 | 6.81 | 6.80 |
| —.050 | 6.78 | 6.76 | 6.75 | 6.73 | 6.71 | 6.70 | 6.68 | 6.66 | 6.65 | 6.63 |
| —.060 | 6.61 | 6.60 | 6.58 | 6.56 | 6.54 | 6.53 | 6.51 | 6.49 | 6.48 | 6.46 |
| —.070 | 6.44 | 6.43 | 6.41 | 6.39 | 6.38 | 6.36 | 6.34 | 6.33 | 6.31 | 6.29 |
| —.080 | 6.28 | 6.26 | 6.24 | 6.22 | 6.21 | 6.19 | 6.17 | 6.16 | 6.14 | 6.12 |
| —.090 | 6.11 | 6.09 | 6.07 | 6.06 | 6.04 | 6.02 | 6.01 | 5.99 | 5.97 | 5.96 |
| —.100 | 5.94 | 5.92 | 5.90 | 5.89 | 5.87 | 5.85 | 5.84 | 5.82 | 5.80 | 5.79 |
| —.110 | 5.77 | 5.75 | 5.74 | 5.72 | 5.70 | 5.69 | 5.67 | 5.65 | 5.63 | 5.62 |
| —.120 | 5.60 | 5.58 | 5.57 | 5.55 | 5.53 | 5.52 | 5.50 | 5.48 | 5.47 | 5.45 |
| —.130 | 5.43 | 5.42 | 5.40 | 5.38 | 5.37 | 5.35 | 5.33 | 5.31 | 5.30 | 5.28 |
| —.140 | 5.26 | 5.25 | 5.23 | 5.21 | 5.20 | 5.18 | 5.16 | 5.15 | 5.13 | 5.11 |
| —.150 | 5.10 | 5.09 | 5.06 | 5.04 | 5.03 | 5.01 | 4.99 | 4.98 | 4.96 | 4.94 |
| —.160 | 4.93 | 4.91 | 4.89 | 4.88 | 4.86 | 4.84 | 4.83 | 4.81 | 4.79 | 4.78 |
| —.170 | 4.76 | 4.74 | 4.72 | 4.71 | 4.69 | 4.67 | 4.66 | 4.64 | 4.62 | 4.61 |
| —.180 | 4.59 | 4.57 | 4.56 | 4.54 | 4.52 | 4.51 | 4.49 | 4.47 | 4.46 | 4.44 |
| —.190 | 4.42 | 4.40 | 4.39 | 4.37 | 4.35 | 4.34 | 4.32 | 4.30 | 4.29 | 4.27 |
| —.200 | 4.25 | 4.24 | 4.22 | 4.20 | 4.19 | 4.17 | 4.15 | 4.13 | 4.12 | 4.10 |
| —.210 | 4.08 | 4.07 | 4.05 | 4.03 | 4.02 | 4.00 | 3.98 | 3.97 | 3.95 | 3.93 |
| —.220 | 3.92 | 3.90 | 3.88 | 3.87 | 3.85 | 3.83 | 3.81 | 3.80 | 3.78 | 3.76 |

27°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.030 | 7.10 | 7.08 | 7.07 | 7.05 | 7.03 | 7.02 | 7.00 | 6.98 | 6.97 | 6.95 |
| —.040 | 6.93 | 6.92 | 6.90 | 6.88 | 6.87 | 6.85 | 6.83 | 6.82 | 6.80 | 6.78 |
| —.050 | 6.76 | 6.75 | 6.73 | 6.71 | 6.70 | 6.68 | 6.66 | 6.65 | 6.63 | 6.61 |
| —.060 | 6.60 | 6.58 | 6.56 | 6.55 | 6.53 | 6.51 | 6.50 | 6.48 | 6.46 | 6.45 |
| —.070 | 6.43 | 6.41 | 6.40 | 6.38 | 6.36 | 6.34 | 6.33 | 6.31 | 6.29 | 6.28 |
| —.080 | 6.26 | 6.24 | 6.23 | 6.21 | 6.19 | 6.18 | 6.16 | 6.14 | 6.13 | 6.11 |
| —.090 | 6.09 | 6.08 | 6.06 | 6.04 | 6.03 | 6.01 | 5.99 | 5.98 | 5.96 | 5.94 |
| —.100 | 5.92 | 5.91 | 5.89 | 5.87 | 5.86 | 5.84 | 5.82 | 5.81 | 5.79 | 5.77 |
| —.110 | 5.76 | 5.74 | 5.72 | 5.71 | 5.69 | 5.67 | 5.66 | 5.64 | 5.62 | 5.61 |
| —.120 | 5.59 | 5.57 | 5.56 | 5.54 | 5.52 | 5.50 | 5.49 | 5.47 | 5.45 | 5.44 |
| —.130 | 5.42 | 5.40 | 5.39 | 5.37 | 5.35 | 5.34 | 5.32 | 5.30 | 5.29 | 5.27 |
| —.140 | 5.25 | 5.24 | 5.22 | 5.20 | 5.19 | 5.17 | 5.15 | 5.14 | 5.12 | 5.10 |
| —.150 | 5.09 | 5.07 | 5.05 | 5.03 | 5.02 | 5.00 | 4.98 | 4.97 | 4.95 | 4.93 |
| —.160 | 4.92 | 4.90 | 4.88 | 4.87 | 4.85 | 4.83 | 4.82 | 4.80 | 4.78 | 4.77 |
| —.170 | 4.75 | 4.73 | 4.72 | 4.70 | 4.68 | 4.67 | 4.65 | 4.63 | 4.61 | 4.60 |
| —.180 | 4.58 | 4.56 | 4.55 | 4.53 | 4.51 | 4.50 | 4.48 | 4.46 | 4.45 | 4.43 |
| —.190 | 4.41 | 4.40 | 4.38 | 4.36 | 4.35 | 4.33 | 4.31 | 4.30 | 4.28 | 4.26 |
| —.200 | 4.25 | 4.23 | 4.21 | 4.19 | 4.18 | 4.16 | 4.14 | 4.13 | 4.11 | 4.09 |
| —.210 | 4.07 | 4.06 | 4.04 | 4.03 | 4.01 | 3.99 | 3.98 | 3.96 | 3.94 | 3.93 |

28°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.030 | 7.07 | 7.05 | 7.03 | 7.02 | 7.00 | 6.98 | 6.97 | 6.95 | 6.93 | 6.92 |
| —.040 | 6.90 | 6.88 | 6.87 | 6.85 | 6.83 | 6.82 | 6.80 | 6.78 | 6.77 | 6.75 |
| —.050 | 6.73 | 6.72 | 6.70 | 6.68 | 6.67 | 6.65 | 6.63 | 6.61 | 6.60 | 6.58 |
| —.060 | 6.56 | 6.55 | 6.53 | 6.51 | 6.50 | 6.48 | 6.46 | 6.45 | 6.43 | 6.41 |
| —.070 | 6.40 | 6.38 | 6.36 | 6.35 | 6.33 | 6.31 | 6.30 | 6.28 | 6.26 | 6.25 |
| —.080 | 6.23 | 6.21 | 6.20 | 6.18 | 6.16 | 6.15 | 6.13 | 6.11 | 6.10 | 6.08 |
| —.090 | 6.06 | 6.05 | 6.03 | 6.01 | 6.00 | 5.98 | 5.96 | 5.95 | 5.93 | 5.91 |
| —.100 | 5.90 | 5.88 | 5.86 | 5.84 | 5.83 | 5.81 | 5.79 | 5.78 | 5.76 | 5.74 |
| —.110 | 5.73 | 5.71 | 5.69 | 5.68 | 5.66 | 5.64 | 5.63 | 5.61 | 5.59 | 5.58 |
| —.120 | 5.56 | 5.54 | 5.53 | 5.51 | 5.49 | 5.48 | 5.46 | 5.44 | 5.43 | 5.41 |
| —.130 | 5.39 | 5.38 | 5.36 | 5.34 | 5.33 | 5.31 | 5.29 | 5.28 | 5.26 | 5.24 |
| —.140 | 5.23 | 5.21 | 5.19 | 5.18 | 5.16 | 5.14 | 5.12 | 5.11 | 5.09 | 5.07 |
| —.150 | 5.06 | 5.04 | 5.02 | 5.01 | 4.99 | 4.97 | 4.96 | 4.94 | 4.92 | 4.91 |
| —.160 | 4.89 | 4.87 | 4.86 | 4.84 | 4.82 | 4.81 | 4.79 | 4.77 | 4.76 | 4.74 |
| —.170 | 4.72 | 4.71 | 4.69 | 4.67 | 4.66 | 4.64 | 4.62 | 4.61 | 4.59 | 4.57 |
| —.180 | 4.56 | 4.54 | 4.52 | 4.51 | 4.49 | 4.47 | 4.46 | 4.44 | 4.42 | 4.40 |
| —.190 | 4.39 | 4.37 | 4.35 | 4.34 | 4.32 | 4.30 | 4.29 | 4.27 | 4.25 | 4.24 |
| —.200 | 4.22 | 4.20 | 4.19 | 4.17 | 4.15 | 4.14 | 4.12 | 4.10 | 4.09 | 4.07 |
| —.210 | 4.05 | 4.04 | 4.02 | 4.00 | 3.99 | 3.97 | 3.95 | 3.94 | 3.92 | 3.90 |

29°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.030 | 7.03 | 7.02 | 7.00 | 6.98 | 6.97 | 6.95 | 6.93 | 6.92 | 6.90 | 6.88 |
| —.040 | 6.87 | 6.85 | 6.83 | 6.82 | 6.80 | 6.78 | 6.77 | 6.75 | 6.73 | 6.72 |
| —.050 | 6.70 | 6.68 | 6.67 | 6.65 | 6.63 | 6.62 | 6.60 | 6.58 | 6.57 | 6.55 |
| —.060 | 6.53 | 6.52 | 6.50 | 6.48 | 6.47 | 6.45 | 6.43 | 6.42 | 6.40 | 6.38 |
| —.070 | 6.37 | 6.35 | 6.33 | 6.32 | 6.30 | 6.28 | 6.27 | 6.25 | 6.23 | 6.22 |
| —.080 | 6.20 | 6.18 | 6.17 | 6.15 | 6.13 | 6.12 | 6.10 | 6.08 | 6.07 | 6.05 |
| —.090 | 6.03 | 6.02 | 6.00 | 5.98 | 5.97 | 5.95 | 5.93 | 5.92 | 5.90 | 5.88 |
| —.100 | 5.87 | 5.85 | 5.83 | 5.82 | 5.80 | 5.78 | 5.77 | 5.75 | 5.73 | 5.72 |
| —.110 | 5.70 | 5.68 | 5.67 | 5.65 | 5.63 | 5.61 | 5.60 | 5.58 | 5.56 | 5.55 |
| —.120 | 5.53 | 5.51 | 5.50 | 5.48 | 5.46 | 5.45 | 5.43 | 5.41 | 5.40 | 5.38 |
| —.130 | 5.36 | 5.35 | 5.33 | 5.31 | 5.30 | 5.28 | 5.26 | 5.25 | 5.23 | 5.21 |
| —.140 | 5.20 | 5.18 | 5.16 | 5.15 | 5.13 | 5.11 | 5.10 | 5.08 | 5.06 | 5.05 |
| —.150 | 5.03 | 5.01 | 5.00 | 4.98 | 4.96 | 4.95 | 4.93 | 4.91 | 4.90 | 4.88 |
| —.160 | 4.86 | 4.85 | 4.83 | 4.81 | 4.80 | 4.78 | 4.76 | 4.75 | 4.73 | 4.71 |
| —.170 | 4.70 | 4.68 | 4.66 | 4.65 | 4.63 | 4.61 | 4.60 | 4.58 | 4.56 | 4.55 |
| —.180 | 4.53 | 4.51 | 4.50 | 4.48 | 4.46 | 4.45 | 4.43 | 4.41 | 4.40 | 4.38 |
| —.190 | 4.36 | 4.35 | 4.33 | 4.31 | 4.30 | 4.28 | 4.26 | 4.25 | 4.23 | 4.21 |
| —.200 | 4.20 | 4.18 | 4.16 | 4.15 | 4.13 | 4.11 | 4.10 | 4.08 | 4.06 | 4.05 |
| —.210 | 4.03 | 4.01 | 4.00 | 3.98 | 3.96 | 3.95 | 3.93 | 3.91 | 3.90 | 3.88 |

30°C.

| *VOLTS* | *.000* | *.001* | *.002* | *.003* | *.004* | *.005* | *.006* | *.007* | *.008* | *.009* |
|---|---|---|---|---|---|---|---|---|---|---|
| —.030 | 7.02 | 7.00 | 6.98 | 6.97 | 6.95 | 6.93 | 6.92 | 6.90 | 6.88 | 6.87 |
| —.040 | 6.85 | 6.83 | 6.82 | 6.80 | 6.78 | 6.77 | 6.75 | 6.73 | 6.72 | 6.70 |
| —.050 | 6.68 | 6.67 | 6.65 | 6.63 | 6.62 | 6.60 | 6.58 | 6.57 | 6.55 | 6.53 |
| —.060 | 6.52 | 6.50 | 6.48 | 6.47 | 6.45 | 6.43 | 6.42 | 6.40 | 6.38 | 6.37 |
| —.070 | 6.35 | 6.33 | 6.32 | 6.30 | 6.28 | 6.27 | 6.25 | 6.23 | 6.22 | 6.20 |
| —.080 | 6.19 | 6.17 | 6.15 | 6.14 | 6.12 | 6.10 | 6.09 | 6.07 | 6.05 | 6.04 |
| —.090 | 6.02 | 6.00 | 5.99 | 5.97 | 5.95 | 5.94 | 5.92 | 5.90 | 5.89 | 5.87 |
| —.100 | 5.85 | 5.84 | 5.82 | 5.80 | 5.79 | 5.77 | 5.75 | 5.74 | 5.72 | 5.70 |
| —.110 | 5.69 | 5.67 | 5.65 | 5.64 | 5.62 | 5.60 | 5.59 | 5.57 | 5.55 | 5.54 |
| —.120 | 5.52 | 5.50 | 5.49 | 5.47 | 5.45 | 5.44 | 5.42 | 5.40 | 5.39 | 5.37 |
| —.130 | 5.35 | 5.34 | 5.32 | 5.30 | 5.29 | 5.27 | 5.25 | 5.24 | 5.22 | 5.20 |
| —.140 | 5.19 | 5.17 | 5.15 | 5.14 | 5.12 | 5.10 | 5.09 | 5.07 | 5.05 | 5.04 |
| —.150 | 5.02 | 5.00 | 4.99 | 4.97 | 4.95 | 4.94 | 4.92 | 4.90 | 4.89 | 4.87 |
| —.160 | 4.85 | 4.84 | 4.82 | 4.80 | 4.79 | 4.77 | 4.75 | 4.74 | 4.72 | 4.70 |
| —.170 | 4.69 | 4.67 | 4.65 | 4.64 | 4.62 | 4.61 | 4.59 | 4.57 | 4.56 | 4.54 |
| —.180 | 4.52 | 4.51 | 4.49 | 4.47 | 4.46 | 4.44 | 4.42 | 4.41 | 4.39 | 4.37 |
| —.190 | 4.36 | 4.34 | 4.32 | 4.31 | 4.29 | 4.27 | 4.26 | 4.24 | 4.22 | 4.21 |
| —.200 | 4.19 | 4.17 | 4.16 | 4.14 | 4.12 | 4.11 | 4.09 | 4.07 | 4.06 | 4.04 |
| —.210 | 4.02 | 4.01 | 3.99 | 3.97 | 3.96 | 3.94 | 3.92 | 3.91 | 3.89 | 3.87 |

5. The quinhydrone electrode is unsuitable for measurements of pH of alkaline solutions.

6. Disregard the minus signs in table 28:1. For practical use, all values in the table can be regarded as positive numbers. The negative voltage, 0.069, for example is treated as though it were really 0.060 plus 0.009 in converting it to pH units.

## THE PHOSPHATASE TEST

The test for the presence of the enzyme phosphatase is a practical and reliable method for ascertaining when milk has been properly pasteurized. The amount of the enzyme present in raw milk from individual cows is not constant but it is always present. The phosphatase content of mixed milk from a herd is less variable than that in the milk of individual animals.

The heat of proper pasteurization destroys all or practically all of the phosphatase enzyme in milk. Delicate tests have been devised to detect and measure the amount of the enzyme in milk and milk products, including cheese. Burgwald (1939) reviewed the literature on the application of the phosphatase test for detecting irregularities in the pasteurization of milk and its products. He pointed out that variations of 1° F. in pasteurizing temperature, 5 minutes in holding time, or the presence of 0.1 per cent of raw milk could be detected easily by the various laboratory tests available at that time for detecting improperly pasteurized milk.

Compact kits for testing milk for phosphatase are now available. They contain all necessary equipment and chemicals for a simplified procedure which is sufficiently sensitive for factory work. They are known as "Field tests for phosphatase." They can be obtained from Paul Lewis Laboratories, Inc., Milwaukee 3, Wis., and Eimer and Amend Company, New York 14, N. Y.

Cheese made from phosphatase negative milk does not become phosphatase positive during the making and curing processes, according to the findings of Lampert (1945) and Sanders and Sager (1946). Caulfield and Martin (1945) applied the New York City field phosphatase test to cheese, and found that all samples of fresh Cheddar cheese with an initial negative phosphatase reaction remained negative to the test for at least 6 months. Such evidence indicates that regular testing of heated milk provides an excellent method of knowing whether the cheese itself will conform to legal standards for a phosphatase negative product.

Testing milk for phosphatase with the rapid field tests that are available is a simpler procedure than testing cheese for the enzyme. Testing of milk for phosphatase is recommended for routine checking of the efficiency of pasteurization in factory practice.

## TEST FOR PHOSPHATASE IN CHEDDAR CHEESE

Sanders and Sager (1946) developed a modification of the phosphatase test to be used in the detection of imperfect pasteurization of milk and of Cheddar cheese made from such milk. Later these same authors (1947) described methods of testing for phosphatase in other varieties of cheese and in other dairy products. The emphasis placed upon these methods by the Food and Drug Administration (Federal Security Agency, 1947) makes it desirable to give a complete description of them. The descriptions of the test that follow, abridge the instructions of Sanders and Sager (1946).

### Reagents

*Barium buffer.* Twenty-five grams of C.P. barium hydroxide ($Ba(OH)_2 \cdot 8\,H_2O$, fresh) is dissolved in distilled water and diluted to 500 ml. Eleven grams of C.P. boric acid is likewise dissolved and diluted to 500 ml. Each solution is warmed to

122° F.; they are mixed together, cooled to room temperature, filtered, and filtrate is kept in a tightly stoppered bottle.

*Color-development buffer.* Six grams of sodium metaborate ($NaBO_2$) is mixed with 20 grams of sodium chloride, dissolved in distilled water, and diluted to 1 liter. The sodium metaborate can be obtained from Amend Drug and Chemical Company, 117 East 24th St., New York 10, N. Y.

*(BQC) 2,6-dibromoquinonechloroimine solution* (Gibb's reagent) is prepared by dissolving 40 mg. of the BQC powder in 10 ml. of methyl or ethyl alcohol. When it is held in a dark glass dropper bottle in the ice tray of a refrigerator it remains stable for at least a month. It is discarded when it begins to turn brown.

*(CQC) 2,6-dichloroquinonechloroimine* is substituted for BQC in the field test. When this is done the color standards must be prepared with the CQC reagent.

*Buffer substrate.* Phenol-free, crystalline disodium phenyl phosphate is used. It can be obtained, relatively pure, from Applied Research Institute, 139 Fifth Avenue, New York 10, N. Y. A stock solution is made by dissolving 1 gram in 9 ml. of the *color-development buffer.* Any free phenol in this solution is removed by adding 1 drop of BQC, holding at room temperature for 30 minutes and extracting the color with 5 ml. of n-butyl alcohol. The alcohol is drawn off and discarded. The extraction is repeated if there is much blue color in the alcohol, but usually this is unnecessary. This stock solution is held at 40° to 50°F. If several days elapse before the solution is used the extraction is repeated. This stock solution is converted to fresh buffer substrate for daily use by adding 1 ml. of it to 100 ml. of the *barium buffer.* The buffer substrate is held in a refrigerator.

*Protein precipitant.* Six grams of zinc sulfate ($ZnSO_4 \cdot 7H_2O$) is dissolved in distilled water and made up to 100 ml. except when it is necessary to add copper sulfate just before the solution is diluted to 100 ml. One-tenth of a gram of copper sulfate ($CuSO_4 \cdot 5H_2O$) is added to the above solution when the protein precipitant is used for testing fresh cheese that is only a few days old, or if it is used in making the rapid field test, or if it is used in any test in which the butyl alcohol extraction method is applied.

*Butyl alcohol.* The n-butyl alcohol with a boiling point of 116° to 118° C. is used for making standards and quantitative analyses. The pH is adjusted by mixing 50 ml. of the *color-development buffer* with 1 liter of the butyl alcohol.

*Phenol standards.* One gram of U.S.P. phenol is placed in a liter flask with about 700 ml. of distilled water. In this flask are then mixed together 150 ml. of the *color-development buffer*, 3 ml. of chloroform, and sufficient distilled water to give exactly 1000 ml. of solution. This stock solution contains 1 mg. of phenol per milliliter.

The stock solution is then used to make up more dilute solutions required for the color standards. One ml. of the stock solution is diluted to 1000 ml. with distilled water and thoroughly mixed. One milliliter of this dilution contains 1 mmg. (0.000001 gram, or 1 microgram, or gamma, or unit) of phenol. A series of other color standards are made by diluting various amounts of the stock solution with required amounts of distilled water. The common standards consist of 2 ml. of the stock solution diluted to 1000 ml.; 5 ml. to 1000 ml.; 5 ml. to 500 ml.; 10 ml. to 500 ml.; and 20 ml. to 500 ml. These color standard solutions contain, respectively, 2, 5, 10, 20, and 40 mmg. or units of phenol per milliliter.

*Color standards.* The color standards are prepared in test tubes. One test tube is provided for each standard. Into it are placed 1 ml. of the desired color standard dilution, 1 ml. of 0.05 per cent solution of copper sulfate, and enough of the *color development buffer* to bring the total volume to 10 ml. Four drops of BQC (or CQC if that reagent is to be used) is added to each tube. The contents of the tube are mixed and held for at least 30 minutes at room temperature to permit the color to develop. The mixture must be extracted with n-butyl alcohol at this time if the n-butyl alcohol extraction method is to be followed in making the test. This is done by adding 5 ml. of the alcohol and inverting the tube slowly several times. This concentrates the color in the alcohol layer. The alcohol extraction method is used for tests which show 0.5 to 5 units of color and also when it is desired to obtain a quantitative estimate of the number of units.

The color standards are stored at 40° to 50°F. for visual comparisons of colors obtained with samples of cheese to be tested.

**Procedure for the laboratory test**

1. Remove a sample of cheese for testing by plugging the cheese with a *clean* trier. Place the plug in a test tube, close the

tube with a stopper, and hold in a refrigerator until it can be tested. Touch the cheese only with a *clean* knife or spatula while taking and weighing the sample.

2. Weigh 0.5 grams of cheese on a watch glass and place it in a culture tube 16 or 18 x 150 mm.

3. Crush the sample in the tube with a glass rod; add exactly 1 ml. of the buffer substrate; thoroughly crush the cheese and disperse it in the reagent. Add 8 ml. more of the reagent so there will be a total of 9 ml. of the buffer substrate in the tube. Mix thoroughly.

4. Wrap a piece of filter paper, about 1 inch square, around the glass rod, draw the rod through it so that the rod is wiped clean. Drop the piece of paper with its accumulated cheese material into the culture tube; stopper the tube, and mix the contents by shaking it vigorously.

5. Incubate the tube and its contents in a water bath at 99° to 100°F. for 1 hour. Shake the tube occasionally.

6. Heat the contents of the tube to not less than 194°F. by placing it in boiling water for 1 minute; cool it to room temperature. Temperatures can be checked with a thermometer in another comparable tube.

7. Add 1 ml. of zinc (or zinc-copper) precipitant, mix and filter through a 9-cm. Whatman No. 42 filter paper.

The zinc precipitant is used for cured cheese, and the zinc-copper precipitant is used for fresh cheese, or for tests in which butyl alcohol is to be added for extraction of color.

8. Measure 5 ml. of the filtrate with a pipette and place it in a clean tube with 5 ml. of the *color-development buffer.* The amount of filtrate now in the tube equals 0.25 grams of the original cheese sample. Add 4 drops of BQC, mix the contents of the tube and hold at room temperature for 30 minutes or at 99° to 100°F. for 15 minutes.

9. After the incubation period a blue color will be visible in tests containing phosphatase values of 5 units or more in the 0.25 gram of cheese in the tube.

For tests with less than this amount of blue color the butyl alcohol extraction method is used. Five milliliters of n-butyl alcohol is added to the tube. The tube is stoppered and inverted slowly several times. The blue color in the alcohol is compared with the prepared color standards to estimate the units of color, or phenol equivalents in mmg. in the 0.25 gram of cheese sample.

10. It is necessary to run a blank test on every sample tested

This is done by weighing the 0.5 gram sample, crushing it in the tube, and heating it to 194 F. *before* adding the *buffer substrate*. Excessive stickiness of the sample in heating can be prevented by crushing and mixing the cheese with 1 ml. of *barium buffer* in place of 1 ml. of *buffer substrate*. After the mixture is heated to 194 F. the remaining 8 ml. of *buffer substrate* is added and the test is completed in the manner described in steps (4) through (9).

### INTERPRETATION

Sanders and Sager (1946), on the basis of their experimental data in perfecting this analytical procedure, suggest that values greater than 3 mmg. of phenol for 0.25 gram of cheese are indicative of under-pasteurization or of contamination of the pasturized milk with raw milk.

**Procedure for the rapid field test**

1. Crush and mix thoroughly 0.5 gram of cheese with a total of 9 ml. of *buffer substrate* as directed in the laboratory test.

2. Incubate the tube and its contents for 30 minutes at 99° to 100°F.

3. Precipitate the protein with the *zinc-copper reagent*, add 8 drops of CQC, and mix thoroughly.

4. Allow 15 minutes at room temperature for the color to develop. The color may be extracted with 5 ml. of n-butyl alcohol for greater precision in using the color standards. Three units (3 mmg. of phenol) of color for 0.25 gram of cheese are indicative of under-pasteurization.

5. Run a blank determination on 0.5 gram of cheese in the manner described in steps (1) through (4) except heat the cheese to 194°F. *before* adding the *buffer substrate*.

### PRECAUTIONS

1. It is best to extract any free phenol from the stock solution of *buffer substrate* just before it is used.

2. Crystalline disodium phenyl phosphate and BQC are less perishable if kept at 25° to 32°F.

3. Glassware and stoppers should be soaked in hot running water after they have been thoroughly cleaned.

4. Barium hydroxide and *barium buffer* must be kept in closed containers to prevent absorption of carbon dioxide.

5. Only glass or cork stoppers should be used in the butyl

alcohol bottles; plastic closures should not be used on any containers.

### TEST FOR PHOSPHATASE IN MILK

The Sanders and Sager (1946) modification of the phosphatase test for application to milk is presented here as a logical method to follow when using their procedures for detecting the presence of phosphatase in cheese.

#### Reagents

*Barium buffer.* The mixture of barium hydroxide and boric acid is prepared in the manner described for use in the test on cheese. Dilute the necessary amount of this mixture with an equal amount of distilled water for use in preparing the *buffer substrate.*

*Buffer substrate.* The stock solution of disodium phenyl phosphate substrate is prepared and purified as described under the test on cheese. The stock solution is converted to fresh *buffer substrate* for daily use by adding 1 ml. of it to 100 ml. of the diluted *barium buffer.*

*Protein precipitant.* Zinc-copper precipitant is prepared by mixing 3 grams of zinc sulfate ($ZnSO_4 \cdot 7H_2O$) with 0.6 gram of copper sulfate ($CuSO_4 \cdot 5H_2O$) and diluting the mixture to 100 ml. with distilled water.

*Other reagents.* The other reagents are prepared in the manner described in the test for phosphatase in cheese. These reagents include: the *color-development buffer, BQC solution, CQC solution, butyl alcohol,* and *phenol standards.*

#### Procedure for laboratory test for phosphatase in milk

1. Measure 1 ml. of milk sample into a tube 16 or 18 x 150 mm. The sample should be well mixed. Add 8 ml. of *buffer substrate* for milk and mix it thoroughly with the milk.

2. Incubate the mixture in a water bath at 99° to 100°F. for 1 hour. Shake the tube occasionally.

3. Heat the mixture to 194°F. or more by placing the tube in a beaker of boiling water for 1 minute, then cool to room temperature.

4. Add 1 ml. of *zinc-copper precipitant* for milk, mix, and filter through 9-cm. Whatman No. 42 filter paper.

5. Mix together 5 ml. of the filtrate, 5 ml. of *color-development buffer*, 2 drops of *BQC* and hold at room temperature for 30 minutes or at 99° to 100°F. for 15 minutes.

6. Run a blank determination when new lots of reagents are used. Follow the procedures described above but heat the 1 ml. of milk being tested to 194°F. *before* adding the *buffer substrate*.

7. As little as 1 mmg. of phenol can be detected by sight in this test so that extraction with n-butyl alcohol is only necessary when greater precision is desired. The extraction is made by the method described in the test for phosphatase in cheese.

8. The final observation of the color is made on half the original total quantity of liquid so the results must be stated as units of color or phenol equivalents in mmg. for 0.5 ml. of milk.

**Procedure for the rapid field test for phosphatase in milk**

1. Measure 1 ml. of thoroughly mixed sample of milk into a tube and add 8 ml. of the *buffer substrate* for milk.

2. Mix the contents of the tube and incubate for 30 minutes at 99° to 100°F.

3. Add to the contents of the tube 1 ml. of *zinc-copper* precipitant for milk, 6 drops of CQC solution, and mix thoroughly.

4. Hold for 15 minutes at room temperature and observe the color. For greater precision, the color can be extracted with n-butyl alcohol as described in the test for phosphatase in cheese.

5. Make a blank determination to check reagents by using this same procedure, but heat the milk to 194°F. *before* adding the *buffer substrate* for milk.

## PRECAUTIONS

Observe the same precautions in making the tests for phosphatase in milk as have been listed for the making of the test on cheese.

## INTERPRETATIONS

Sanders and Sager (1946) suggested that values of phenol greater than 2 mmg. for 0.5 ml. should be considered as indicative of under-pasteurization or contamination with raw milk.

## OTHER FIELD TESTS

Field tests kits containing equipment, reagents, and instructions for testing for phosphatase in milk can be obtained from dairy supply companies and certain chemical supply companies. These kits are practical for use in plants where frequent checks are made on the pasteurized milk. They are particularly useful when extensive laboratory facilities and a trained technician are not available for this phase of control work.

## MISCELLANEOUS TESTS

### Walker Test for Estimating Casein in Milk

When formaldehyde is added to milk, it reacts with the $-NH_2$ groups of the protein molecules. The result of the reaction is to make the milk more acid. The acidity produced in this manner is directly proportional to the quantity of the proteins present. Walker (1914) proposed that this relationship could be used to estimate the casein content of milk, although the relation could not be exactly correct because casein and the other proteins of milk were not always present in exactly the same proportions.

The Walker test has been studied by several investigators. Pyne (1932, 1933) believed that the addition of an oxalate eliminated some of the inaccuracies caused by the interference of soluble calcium salts normally present in milk. McDowall and Dolby (1936) decided to omit the oxalate treatment for factory practice. De Vleeschauwer and Heyndrickx (1947) found the Pyne method dependable.

McDowall (1935) and McDowall and Dolby (1936) suggested several modifications from the original instructions of Walker. These included: the use of a larger sample of milk; the preparation of a color standard made by tinting milk with a 0.01 per cent solution of rosaniline acetate or rosaniline hydrochloride; and the measurement of, and allowance for, acidity of formaldehyde solution rather that its neutralization before use.

**Apparatus and reagents for the modified Walker casein test**

The same apparatus used for measuring titratable acidity of milk is needed for the Walker casein test. In addition there must be provided: 1 ml. pipette, 2 ml. or 4 ml. pipette, and a color standard, such as the Nafis color comparison rod for the acidity test.

The reagents needed are the usual N/10 sodium hydroxide solution which is used in the test for titratable acidity in milk, an indicator solution consisting of 1 gram of phenolphthalein in 100 milliliters of alcohol, and water white formaldehyde of 40 per cent concentration.

**Procedure**

1. Add 1 ml. of formaldehyde and 1 ml. of the phenolphthalein solution to 17.6 ml. (Babcock pipette) of distilled water. Add N/10 sodium hydroxide solution from the burette of the acidimeter until the pink color matches that of the color comparison rod. This amount of alkali used to neutralize the formaldehyde is the "formaldehyde acidity correction factor." This titration must be made at intervals of one to two weeks while the formaldehyde is being used.

2. Adjust the temperature of the milk to be tested to 70° to 75°F. and mix the sample as in testing for fat.

3. Pipette 17.6 ml. of milk into the white titration cup and add 1 ml. of phenolphthalein solution.

4. Add the N/10 sodium hydroxide from the burette of the acidimeter until the pink color matches that of the color comparison rod which is used to stir the sample while the alkali is being added.

5. Measure 4 ml. of formaldehyde with a pipette and add it to the neutralized sample. The color will immediately turn white.

6. Adjust the level of alkali in the burette to the 0 mark.

7. Add alkali from the burette to the decolorized sample. Stir the sample with the color comparison rod while adding the alkali until the desired pink color is attained.

8. Note the reading on the burette. Subtract the "formaldehyde acidity correction factor." Multiply the result by 0.8335 to get the per cent of casein in the sample.

For example: assume that the "formaldehyde acidity correction factor" was 0.25 ml. and that the alkali required to restore the pink color to the formaldehyde-treated sample was 3.01 ml. Subtract 0.25 from 3.01 to get 2.76. This represents the alkali required to restore the color of sample after allowing for the acidity of the formaldehyde. Multiply 2.76 by 0.8335 to get 2.30, the per cent of casein in the sample.

## LACTOMETER TEST

The Quevenne lactometer is used for measuring the density of milk. The density of milk is closely related to the solids content of the milk so, by using suitable formulas, the lactometer test with the fat test can be used to estimate the approximate percentages of solids-not-fat and total solids in milk.

## Procedure

The sample of milk to be tested is thoroughly mixed and heated to approximately 60° F. The temperature should be not less than 50° F. nor more than 70° F. The sample of milk is placed in a cylinder deep enough to float the lactometer. The lactometer is lowered into the milk. More milk sample is added, if necessary, to bring the level of the milk as close as possible to the top; this makes it easier to read the lactometer scale. The lactometer reading is made at the point on the scale that touches the upper edge of the meniscus. The reading is made when the lactometer has been in the milk for about one minute. The temperature of the milk is observed at the time the lactometer is read. For every degree above 60° F. a correction factor of 0.1 is added to the lactometer reading; the same correction factor is subtracted when the lactometer is read at a temperature less than 60° F. For example: if the lactometer reading is 29 at 65° F. then the corrected reading is 29.5; if the reading is 29 at 54° F. then the corrected reading is 28.4.

## Application

The Quevenne lactometer reading is converted to specific gravity by merely dividing the reading by 1000 and adding 1. For example: the lactometer reading of 29 corresponds to a specific gravity of 1.029; a reading of 28.4 corresponds to a specific gravity of 1.0284.

The second application of the lactometer reading is in the calculation of the approximate solids content of milk. The following formulas were devised by Dr. S. M. Babcock (1897):

(1) Per cent solids-not-fat $= 0.25\ L + 0.2\ F$
(2) Per cent total solids $= 0.25\ L + 1.2\ F$

In these formulas L is the lactometer reading, and F is the percentage of fat in the milk.

Example: The percentage of fat in milk is 3.2; the lactometer reading is 30.8 at 60° F.

$$\begin{aligned}
&\text{(1) Per cent solids-not-fat} &&= 0.25 \times 30.8 + 0.2 \times 3.2\\
& &&= 7.70 \qquad\quad + 0.64\\
& &&= 8.34\%\\
&\text{(2) Per cent total solids} &&= 0.25 \times 30.8 + 1.2 \times 3.2\\
& &&= 7.70 \qquad\quad + 3.84\\
& &&= 11.54\%
\end{aligned}$$

Sharp and Hart (1936) pointed out that the choice of 60°F. as the temperature for reading the lactometer was a most unfortunate one for accurate results. They explained this by the lag in the change of the physical state of the milk fat while milk is being adjusted to this temperature. They showed that more accurate results could be obtained by determining the specific gravity of the milk at 30°C. (86°F.) after heating it to 45°C. (113°F.) for one-half minute. They developed an equation for calculating total solids; this equation was modified by Herrington (1946) to read:

$$\text{Per cent total solids} = 1.2537F + 0.2594\ (Q + 3)$$

In this equation F is the per cent of fat in the milk and Q is the Quevenne lactometer reading at 86°F.

## RENNET TEST FOR RIPENESS OF MILK

The time required for coagulation of milk by rennet is influenced by many factors. Most of these factors, except that of acidity, are relatively constant in the milk of a given factory from day to day. By noting the variations in the time required for coagulation of this milk under uniform conditions it is possible to determine the so-called "ripeness" of the milk. This coagulation time does not actually measure acidity because other factors, such as the composition of the milk, and the like, are involved in this reaction; but it does indicate in a significant manner the changes in the milk which are caused by variations in acidity.

Hastings and Evans (1913) found that, when conditions of making the test were properly regulated, the rennet test was superior in delicacy to the acid titration test in detecting acid formation in milk.

### Apparatus

The apparatus consists of a 1 ml. pipette for measuring rennet, a 25 ml. graduated cylinder, a spatula, and a rennet test cup. On the inside of this cup is a scale of 5 or 10 points that extends from the top to the bottom. The 0 mark on the scale is about one-half inch from the upper edge. In the bottom of the cup is a metal plug with a hole in it about one-twentieth of an inch in diameter. This cup can be purchased from any dairy supply company.

### Procedure for making the rennet test

1. Adjust the temperature of the milk to be tested to the setting temperature of the milk, 86°F.

2. Dilute 1 ml. of rennet extract with 14 ml. of drinking water at 85° to 90°F. This solution must be used at once.

3. Fill the rennet test cup with milk at 86°F. and set it in a level place, such as the corner of the vat, while the milk drains from the hole in the cup.

4. At the instant when the level of the milk exposes the 0 line on the scale, add the rennet solution to the milk and begin stirring as quickly as possible with the spatula. Continue stirring for 10 to 12 seconds to obtain thorough mixing of the milk and rennet. Let the cup remain undisturbed until the milk coagulates and the milk stops flowing through the hole in the bottom of the cup.

5. Read the number of spaces on the cup's scale uncovered by the lowered level of the milk. Report the results as "spaces" on the rennet test cup.

## RENNET TEST FOR STRENGTH OF RENNET

The rennet test can be used to measure the relative strength of two or more lots of rennet extract. Identical milk is used in making all the tests with each of the rennet extracts to be compared. Differences in the tests with different extracts should be verified by repeating tests to eliminate the slight errors in adjustments of temperature, measurements of rennet extract, or the like. The strongest rennet coagulates the milk most rapidly.

## STARTER ACTIVITY TEST

Horrall and Elliker (1947) developed a test to measure the activity of lactic starter used in the making of Cheddar cheese and Cottage cheese. In this test they reconstituted dry skim milk of high quality for the testing medium; this was done to obtain the most dependable results under conditions where the milk supply of the factory might cause difficulty.

### Steps in making the starter activity test

1. Mix 10 grams of high grade, spray-dried dry skim milk with 90 milliliters of distilled water and place it in an Erlenmeyer flask stoppered with cotton.

2. Sterilize the reconstituted milk in the flask at 15 pounds pressure for 10 minutes.

3. Measure out 10 ml. of the sterilized, reconstituted milk with a sterile pipette and place it in a sterile, screw-top, test tube.

4. Adjust the temperature of the tube and its contents to 37.7°C. (99.9°F.) in a water bath.

5. With a sterile pipette, graduated to 0.1 ml., measure 0.3 ml. of the starter to be tested and add it to the 10 ml. of sterile milk in the tube.

6. Incubate the inoculated tube at 37.7°C. (99.9°F.) for 3.5 hours.

7. Empty the 10.3 ml. of the incubated mixture into a clean flask for titration; rinse the tube with 5 ml. of distilled water; add 1 ml. of a 1 per cent solution of phenolphthalein indicator; and titrate with N/10 sodium hydroxide to a faint pink color.

## Interpretation of results

1. An acidity of 0.4 per cent indicates the starter is active.
2. An acidity of 0.3 to 0.35 per cent indicates a "slow" starter.
3. An acidity less than 0.3 per cent indicates that the starter is unsatisfactory for use in Cheddar cheese.

## REFERENCES

Arbuckle, W. S. (1946). J. Dairy Sci., *29*, 431.

Babcock, S. M. (1897). Wis. Agr. Expt. Sta., Bul. 61.

Brown, L. W. and Price, W. V. (1934). J. Dairy Sci., *17*, 33.

Burgwald, L. H. (1939). J. Dairy Sci., *22*, 853.

Caulfield, W. J. and Martin, W. H. (1945). J. Dairy Sci., *28*, 155.

De Vleeschauwer, A. and Heyndrickx, G. (1947). Mededeelingen van de Landbouwhogeschool en de Opzoekingsstations van de Staat te Gent., *12*, No. 2-3:139.

Erekson, A. B. (1946). Nat. Butter & Cheese J., *37*, No. 8:46.

Federal Security Agency, Food and Drug Administration (1947). Federal Register, *12*, No. 37:1192.

Gould, I. A. (1937). J. Dairy Sci., *20*, 625.

Gould, I. A. (1938). J. Dairy Sci., *21*, 379.

Hansen, H. C., Horrall, B. E., Bird, E. W., and Jensen, C. (1945). J. Dairy Sci., *28*, 325.

Hastings, E. G. and Evans, Alice C. (1913). U. S. Dept. Agr., Circ. 210.

Heinemann, B., Herreid, E. O., Josephson, D. V., England, C. W., and Swope, W. D. (1947). J. Dairy Sci., *30*, 963.

Herrington, B. L. (1946). J. Dairy Sci., *29*, 87.

Hood, E. G. (1948). Can. Dairy Ice Cream J., *27*, No. 1:19.

Hood, E. G. and Sproule, W. H. (1944). Can. Dairy Ice Cream J., *23,* No. 6:27.

Horrall, B. E. and Elliker, P. R. (1947). J. Dairy Sci., *30,* 523.

Lampert, Lincoln M. (1945). J. Dairy Sci., *28,* 751.

Marquardt, J. C. (1938). N. Y. (Geneva) Agr. Expt. Sta., Tech. Bul. 249.

McDowall, F. H. (1935). Dairy Research Institute (N.Z.) Palmerston North, Publication No. 68.

McDowall, F. H. and Dolby, R. M. (1936). New Zealand J. Sci. and Technol., *17,* No. 4:619.

Miersch, Raymond and Price, Walter V. (1944). J. Dairy Sci., *27,* 881.

Overman, O. R. and Whitmore, B. F. (1939). Nat. Butter & Cheese J., *30,* No. 2:18.

Pyne, G. T. (1932). Biochem. J., *26,* 1006.

Pyne, G. T. (1933). Biochem. J., *27,* 915.

Sammis, J. L. (1917). Wis. Agr. Ext. Circ. 81.

Sanders, George P. (1938). Ind. Eng. Chem., Anal. Ed., *10,* 275.

Sanders, George P. and Sager, Oscar (1946). J. Dairy Sci., *29,* 737.

Sanders, George P. and Sager, Oscar S. (1947). J. Dairy Sci., *30,* 909.

Sharp, P. F. and Hart, Ray G. (1936). J. Dairy Sci., *19,* 683.

Spicer, D. W. and Price, W. V. (1938). J. Dairy Sci., *21,* 1.

Thibodeau, R. (1946). Le Quebec Laitier, *5,* No. 1:8.

Turner, A. W., Rogers, B., and Conquest, V. (1942). J. Dairy Sci., *25,* 777.

Walker, W. O. (1914). Ind. & Eng. Chem., *6,* 131.

Watson, Paul D. (1927). Ind. & Eng. Chem., *19,* 1272.

Wilster, G. H., Price, W. V., Morris, A. J., Goss, E. F. and Sanders, G. P. (1937). J. Dairy Sci., *20,* 27.

Wilster, G. H., Price, W. V., Morris, A. J., Goss, E. F., and Sanders, G. P. (1940). J. Dairy Sci., *23,* 197.

Winder, W. C., Price, W. V., Swanson, A. M., and Sommer, H. H. Report presented at the Annual Meeting of the National Cheese Institute, Chicago, Ill., May 11, 1948.

# INDEX

Aeration of milk, 104
Acetylmethylcarbinol, 119
Acid, action on bacteria, 117
  action on casein, 6, 143, 321
  action on rennet efficiency, 31
  body, 224, 226
  color, 224, 226
  control, 223
  defects, 223
  finish, 224, 226
  flavor in Cheddar cheese, 223, 226, 228
  lactic, 9, 10
  pH, 224, 226
  source in cheese, 9
  tests, 113, 473
    sensitivity, 114
    significance, 113
    variations, 113
  texture, 224, 226
  titratable, 473
Acid content of Cheddar cheese, 223
Acid-cut color, 254
Acidity, defects, 223, 226
    causes of, 9, 160, 223
    preventions, 224, 226
    remedies, 224, 226
  development, 10
    bacteriophage effect, 90, 133, 226
    Baker's cheese, 424
    Cheddar cheese, 159, 223
    control of, 202, 224, 226
    Cottage cheese, 134, 389, 398
    Cream cheese, 412
  excessive, 223
    control in Cheddar cheese, 224
  herd milk, 159
  increase after coagulation, 146
  insufficient, 226
    control in Cheddar cheese, 226
  measurements, 473
  milk, mixed, 159, 206
  Neufchatel, 427
  normal in Cheddar cheese, 159, 204, 223
  schedule for Cheddar cheese, 159, 204
  starter, 125, 127, 132
  tests, 158
Acidity tests *(cont'd)*
    hot iron, 159, 475
    hydrogen ion concentration, 476
    pH apparatus, 476, 478
    pH of cheese, 479
    pH of liquids, 477
    pH measurement, 476
    pH, tables for conversion, 481
    titratable acidity, 473
  whey, 159, 214, 206, 439
Acidoproteolytic coccus, 87
Acids for process cheese, 356
Activity test for starter, 498
Aged cheese, 290
Agitation of vat contents, 171
Albumin cheese, 8, 437
Albumin in milk, 8
American Association test, 460
American Cheddar cheese, 31
American Dairy Science Association, cheese analysis, 461
  judging contests, 271
  judging contests, effects, 280
  score card, 271
  testing whey for fat, 460
American Public Health Association, 105
Amino acids, 320, 327, 328
Ammonia, 322, 327, 328, 330, 331, 332
Anaerobes in Cheddar cheese, 89
Analysis, lactometer, 495
Analytical methods, 456
Analyzing cheese, 461
Appearance, 286
Ascorbic acid in cheese, 401
Ascorbic acid in milk, 13
Ash of milk, 11, 23, 24
Ayrshire milk, composition, 21, 22

Babcock test, 456
  balances for, 457, 459, 462
  centrifuge, 458
  glassware, 457, 459
  glymol, 459
  reading, 458, 459
  reagents, 457, 459
  sulfuric acid, 457
  torsion balances, 462

Babcock test (*cont'd*)
  buttermilk, 460
  cheese, 461
  cheese sampling, 461
  cream, 459
  milk, 457
  milk sampling, 456
  skim milk, 460
  whey, 460
Bacteria and cheese making, 79
Bacteria, environment, 80
  flavor, 86
  temperature, 80
Bacteria in Cheddar cheese, 85
Bacteria in cheese, 81
  desirable, 83
  undesirable, 87
  sequence, 83, 84
Bacterial changes in milk, 79
Bacterial control in cheese making, 81
Bacterial control in milk for cheese, 82
Bacterial control of milk in cheese making, 140
Bacteriophage, 89, 132
  acid development in presence of, 90, 133, 134
  areas troubled by, 133
  Cheddar cheese, 133
  cheese affected by, 133
  chlorine for, 134
  control, 135, 136
  Cottage cheese, 134
  hypochlorite for, 134
  presumptive tests for, 134
  sanitation, 131
  slow acid development in presence of, 90
  sources of infection, 134, 135
  specificity, 132
*Bacterium casei*, 86
Baker's cheese, acid development, 424
  bacteria, undesirable in, 87
  bagging, 425
  cutting acidity, 424
  description, 423
  distribution, 426
  draining, 425
  manufacture, 424
  preservation, 428
  pressing, 426
  removal of whey, 425
  rennet, 424
  salting, 426
  setting period, 424
  setting temperature, 424
  starter, 84, 424
  yield, 426
Balances for cheese testing, 462
Batch of process cheese, 364
Biological Oxygen Demand, 447
Biological properties of milk, control of, 140
Bitter flavor, 228
Black Diamond cheese, 298
Black discoloration, 254
Bleached color, 254
  discoloration, 255
Blending for process cheese, 359
Blending for processing, acidity of blend, 360
  age of blend, 360
  arrangement of vat lots, 362
  body for blend, 362
  composition for blend, 362
  distribution of vat lots, 362
  flavors for blend, 361
  selection of cheese, 359
  size of blend, 364
  texture for blend, 361
Bloated cheese, 260
B.O.D., 447
Body, defined, 239
  fat effect on, 5
  ideal, 283
  moisture effect on, 2
  physical properties of, 239
  terms describing, corky, 283
    crumbly, 284
    curdy, 284
    dry, 284
    firm, 284
    flaky, 284
    gritty, 284
    mealy, 284
    meaty, 284
    pasty, 284
    rubbery, 284
    salvy, 284
    short, 284
    silky, 284
    smooth, 284
    soft, 284
    solid, 284
    spongy, 284
    sticky, 284
    stiff, 284
    waxy, 284
    weak, 285
Body of ripened Cheddar cheese, 319
Boxes, 200
  fastening, 201
  humidity of air in, 307
  marking, 201

Boxes (*cont'd*)
  pressure-pack, 348
  process cheese, 374
Boxing cheese, 200
Brand for cheese, 197
Breed, milk composition, 20, 21, 22
Brine-soluble protein in cheese, 320, 321
Brown color in Cheddar cheese, 89
Butter fat, *see* Milk fat
Butter from whey cream, 437

Calcium caseinate in milk, 6, 8
Calcium in Cheddar cheese, 324
Calcium in cheese, 404
Calcium chloride, addition to milk, 139, 143
  Cottage cheese, 388
  in milk, 11
Calcium ions, 141
Calcium lactate, 321
Calcium paracaseinate, 321
  action of acid on, 8
  formation by rennin, 7
Calcium phosphate, 11, 324
  insoluble, action of acid on, 142
Calcium salts, 324
  effect on rennet action, 139, 142, 143, 388
Calories in cheese, 404
Canadian Cheddar cheese, 32, 36, 37
Canned cheese, 341
  carbon dioxide absorbents for, 343
  cost of making, 344
  gas production in, 342
  merchandising, 344
  methods of, 343
  precautions, 344
  vacuum packing, 342
Canning Cheddar cheese, 341
Cap cloths, 192
Carbohydrate, in cheese, 404
  in milk, 9
  in whey, 431, 432
Carbon dioxide, absorbent in canned cheese, 343
  in milk, 16
  losses in ripening cheese, 305
Carotene, 325
  in milk, 12
Casein, action of acid on, 6
  action of alkali on, 7
  action of bacteria on, 9
  action of enzymes on, 9
  action of rennin on, 7, 142
  action of salts on, 7
  amount in milk, 19, 21, 24, 26
  changes in ripening, 320
Casein (*cont'd*)
  coagulation, by acid, 6
    by heat, 7
    by rennin, 7
    by salts, 7
  composition, 5, 320
  estimating, 29, 43
  fat-plus-, for milk, 71
  formula for calculation, 29, 43
  functions in cheese, 8
  identity, 6
  losses in whey, 59
  milk payments based on, 71
  moisture retained by, 63
  normal milk, 29
    in New Zealand, 29
  paracasein from, 8
  physical state, 6
  relation to milk fat, 28
    yield, 61
Casein coagulation, 142
  acid, 143
  heat and acid, 144
  rennet and acid, 143
  rennin, 143
Casein/fat ratio, 33, 49
  fat in cheese, 34
  yield relation, 62
Caseinate, calcium, 6, 8
Caseoses, 320, 327, 328
Centrifuging fat tests, 458
Changes in bacteria in milk, 79
Checked rind, 258
Cheddaring in Cheddar cheese making, 177
Cheddar cheese, acidity at cutting, 170
  acidity at dipping, 175
  acidity at milling, 159, 181
  acidity at packing, 159, 178
  acidity at salting, 187
  acidity at setting, 159
  attributes, 280
  blocks of curd, 178
  body, control of, 180
    corky, 240
    crumbly, 240
    curdy, 241
    dry, 241
    ideal, 239, 240, 283
    mealy, 241
    pasty, 242
    sandy, 242
    short, 242
    sticky, 242
    weak, 242
  characteristics, 280

- Cheddar cheese (*cont'd*)
  - cheddaring, body control, 180
    - moisture control, 180
    - texture control, 180
    - time of, 181
  - color, amount, 162
    - defects, 254
    - ideal, 286
  - composition, 31, 32, 36
  - curd, arrangement at dipping, 176
  - characteristics at dipping, 174, 175
  - condition at hooping, 189
  - cutting, 166, 168, 169
  - defects, acidity, 219
    - appearance, 258
    - body, 239
    - color, 254
    - finish, 254, 258
    - flavor, 219
    - defects, moisture, 219
    - texture, 239
  - dipping, 175
    - condition of curd, 174, 176
    - firmness at, 174
    - pH, 175
    - size of cubes at, 174
  - finish, 197, 258, 267, 273, 286
  - flavor, 228, 267, 271, 272, 277, 281, 319, 326. *See* Flavor
    - defects, 228
  - freezing points, 300
  - gas control, 181
  - heating the curd, 171
  - heating maximum, 172
  - hooping, 189
  - hoops, 190, 191
  - hoops, dressing, 191, 193
  - milling, 182
  - packing, 177, 178
  - packing acidity, 178
  - paraffining, 198
  - piling, 179
  - pressing, 194
    - final, 196
  - removal of whey, 173
  - removing cheese from hoops, 196
  - rennet, adding, 163
    - amount, 162
    - temperature for adding, 162
  - settling curd, 170
  - size of cubes, 167
  - starter, addition, 160
    - amount, 161
  - stirring curd after cutting, 171
  - stirring curd at dipping, 177
  - styles, 190
  - texture, ideal, 243, 285
- Cheddar cheese (*cont'd*)
  - turning blocks, 179
  - washing at milling, 184
  - whey composition, 58
  - white specks, 324
  - yield, 55, 62, 67
  - yield in factories, 61. *See* Yield
- Cheese analysis, 461
  - hard cheese sampling, 461
- Cheese boxes, humidity in air in, 307
- Cheesecloth, 192
- Cheese composition, 33
- Cheese curing, *see* Curing, Ripening
- Cheese epidemics, 91
- Cheese factory, 445
  - contamination from air, 449
  - drainage, 446
  - design, 450
  - diagrams of floors, 451
  - exterior, 449, 452
  - equipment, 453
  - floor plans, 451
  - interior, 449, 452
  - location, 445
  - market, distance from, 445
  - minimum requirements, 452
  - personnel, 453
  - planning, 450
  - plant layout, 450
  - premises, 452
  - public opinion, 445
  - sanitation, 454
  - sanitation responsibility, 455
  - sewage disposal, 446, 452
  - sewage systems, 448
  - site, 446
  - space relationships, 451
  - surroundings, 449, 452
  - statement model, 77
  - statements, 76
  - structure, 452
  - toilet facilities, 453
  - wastes, disposal of, 446
  - waste prevention, 447
  - water supply, 446, 452
  - whey tank, 452
- Cheese production, U.S. 432
- Cheese ripening, 138, 150. *See* Curing, Ripening
- Cheese solids, 33
- Chemical changes in Cheddar cheese, 319
- Chemical properties of milk, control of, 138
- Chlorine for sterilizing, 100, 101, 134, 153, 429
- Citric acid, starter aroma, 119

Clarification of milk, 141, 156
Clean milk, test for, 104
Clock procedure for Cheddar cheese, 202
Club cheese, 352
Coagulants, 141
Coagulation of milk, defects, 144
  defects, causes of, 145
  rennin, 142, 143
  signs of, in Cheddar cheese, 163
Coagulation, signs of, 163
Cocci in Cheddar cheese, 86
Cohesiveness of body, 239
Colby cheese, 215
  body, 215, 217
  color, 217
  curing, 217
  defects, 217
  draining, 216
  flavor, 215, 217
  hooping, 216
  keeping properties, 217
  manufacturing, 215
  marking, 217
  qualities, 215
  salting, 216
  texture, 215
  washing curd, 215
Cold-cured Cheddar cheese, 291
  care of, 293
  uses of, 291
Cold-curing, duration for Cheddar cheese, 293
  humidity for Cheddar cheese, 293
  precautions in, 299
  temperature for Cheddar cheese, 293
Cold-pack cheese, 352
Cold-pack Cream cheese, 417. *See* Cream cheese
Color, acid-cut, 254
  adding to milk, 162
  amount for Cheddar cheese, 162
  black discoloration, 254
  bleached, 254
  bleached discoloration, 255
    *B. fluorescens liquefaciens,* 255
    *B. subtilis,* 255
  defects in Cheddar cheese, 89
    black discoloration, 254
    bleached, 254, 255
    mottled, 255
    pale, 254
    rusty spots, 256
    seamy, 257
    wavy, 257
    white specks, 257
    definitions of, acid-cut, 286
Color, defects, definitions *(cont'd)*
    bleached, 286
    faded, 286
    high, 286
    light, 286
    mottled, 286
    red spots, 286
    rusty spots, 286
    seamy, 286
    streaked, 286
    translucent, 286
    uniform, 286
    wavy, 286
    white specks, 286
  effect of fat on, 5
  effect of moisture on, 3
Colostrum, composition, 23
Comminuted cheese, 352
Commission on Standardization of Biological Stains, 110
Composition and body of Cheddar cheese, 37
Composition and quality of Cheddar cheese, 36
Composition, average of Cheddar cheese, 32
Condiments for Cream cheese, 418, 420
Consumer preferences, 219, 290
Cookers, for processing, 366, 368
Cooling milk, 102
  equipment for, 102
  stirring, 102
Coon cheese, 296, 298
Corky body, Cheddar cheese, 240
Cottage cheese, 382
  acid-curd, 384
    cutting time, 398
    firmness, 399
    heating procedure, 398
    manufacture, 397
    setting temperature, 398
    starter, amount, 398
    stirring, 398
  appearance defects, small particles, 403
    watery, 403
    wheying off, 403
  bacteria, undesirable in, 87
  bacteriophage in, 90
  Board of Health regulations, 385
  body defects, 403
    dry, 403
    grainy, 403
    gritty, 403
    hard, 403
    pasty, 403
    rubbery, 403

Cottage cheese (*cont'd*)
    sticky, 403
    soft, 403
    tough, 403
  brine storage, 400
  composition, 399
  creamed, fat content, 382
  cream, homogenizing for, 396
  defects in, 402
  dry skim milk for, 400
  dry skim milk, low-heat for, 400
  flake-type, 382
  flavor defects, 402
    feed, 402
    fermented, 402
    sour, 402
    unclean, 402
    yeasty, 402
  Food and Drug Administration regulations, 385
  freezing, 400
  homogenized, 423
  long-setting, 385
  low-acid, 382
  making from dry skim milk, 401
  milk for, 385
  nutritive value, 404
  pasteurization for, 385
  preservation, 428
  production, 382
    leading areas, 383
    seasonal, 383
  rennet-curd, 386
  rennet-type, 386
  short setting, 384
  starter, 84, 386
  storage, 399
  sweet-curd, 382, 384
    acidity for cutting, 389
    calcium chloride, 388
    coagulators, 388
    creamed curd, fat in, 396
    cream, homogenized for, 296
    creaming, 395, 397
    curd knives, size, 390
    cutting, method, 390
    cutting, time for, 389
    cutting with high acid, 390
    cutting with low acid, 390
    color, 389
    cooking, 390
    dipping, 393
    draining, 394
    firming curd, 392
    heating curd, 390
    racks for draining, 394
Cottage cheese, sweet-curd *(cont'd)*
    refrigeration, 395
    rennet, addition of 387
    rennet variations, effect, 388
    salting, 395
    setting, 386
    starter, long-setting, 387
    starter, short-setting, 386
    sweet-curd, stirring, 390
    table for creaming, 397
    temperature, long-setting, 387
    temperature, short-setting, 386
    washing curd, 394
    whey removal, 393
    yield, 396
  yeast in, 88
Cottage cheese creaming, 395, 397
Cottage cheese curd, 382
Cottage cheese manufacture, variations, 383
Cotton disc, single service, 101
Cows, clean, 98
  healthy, 97
Cowy flavor, Cheddar cheese, 230
Cracked rind, 258
Cream cheese, 406
  acidity for stirring, 412
  bacteria, undesirable in, 87
  bags for draining, 416
  blending for control, 417
  blending for homogenizing, 418
  boxing, 417
  centrifuging curd, 417
  cold-pack method, 417
  cold-pack salting, 417
  composition, uniformity, 409
  cooked-curd method, 407
  curd formation, 411
  definitions, 406
  draining curd, 415
  draining bags, care of, 429
  draining, moisture test, 416
  fat content of, 406
    mix effect on, 408
  fat in mix, rate of drainage effect, 409
    whey drainage, 409
    yield effect, 420
  flavoring, 418
  gums, kinds for, 418
    legal limit, 418
    purpose of, 418
  heating curd, 414
  homogenizing curd, 418
  homogenizing mix, 411
  hot-pack, blending, 418
    composition, 419
    fat in, 419

Cream cheese, hot-pack *(cont'd)*
        flavoring, 420
        gums, 418
        low fat mix, 419
        method, 418
        packaging, 419
        salting, 419
        stabilizers, 418
        standardizing, 418
    hot water heating, 415
    ingredients, 407, 418
    long-setting, 412
    manufacture, 407
    mix, adding water to, 415
        fat and yield, 420
        fat content, 408
        heating, 414
        homogenizing, 411
        pasteurization, 410
        preparation, 407
        titratable acid, 414
    mix fat, whey drainage, 409, 410
    mixing condiments with, 418, 420
    moisture, leakage of, 408
        mix effect, 409
    moisture content, 406
    nutritive value, 404
    packaging, 417
    pasteurizer for, 414
    pasteurizing mix, 410
    pH for stirring, 412
    preservation, 428
    pressing, 416
    rennet for, 412
    rennet variations, 412
    salting, 417
    setting conditions, 412
    setting period changes, 413
    setting temperature, 412
    short-setting, 412 .
    standardizing, hot-pack, 418
    starter, 84, 413
    starter for, 412
    stirring curd, 414
    yield, 420
Cream for process cheese, 356
Cream spreads, Geneva method, 421
Cream test for fat, 459
Creamed Cottage cheese, 382
Crumbly body in Cheddar cheese, 240
Cultures, bacterial control by, 82
Curd, behavior at cutting, 170
    cooking, 148
    cutting, 146, 147
    cutting for Cheddar cheese, 166
    defects, 144
    draining, 149
Curd *(cont'd)*
    dipping, 149
    dipping arrangement, Cheddar, 176
    firming, 145, 149
    formation, 141, 143, 144
    heating, 148
    heating, effect on bacteria, 148
    heating too fast, 148
    pressing, 150
    removal from whey, 149
    salting, 150
    size of particles, 147
    stirring, 148
    sweating of, 147
    water-holding capacity, 146
Curd formation, acid, 143
    Cream cheese, 411
    defects, 144
    defects, causes of, 145
    delayed, 145
    heat and acid, 144
    incomplete, 145
    rennet and acid, 143
    rennin, 142, 143
    uniformity, lack of, 145
Curd knives, Cheddar cheese, 165
    Cottage cheese, sweet-curd, 390
    cutting size, 167
    horizontal, 166
    horizontal, method of using, 168
    vertical, 166
    vertical, method of using, 169
    wide, 167
Curd making, 138
    acidity increase after coagulation, 146
    clarification, 141
    coagulants, 141
    control of milk properties, 138, 139, 140, 141
    curd changes, 145
    cutting, 146
    firming after coagulation, 145
    homogenization, 141
    removal of whey, 149
    standardizing milk, 139
    vacuumizing milk, 141
    water-holding capacity, 146
Curd mill, 182, 183
Curd mill for Cheddar cheese, 182
Curd structure of Cheddar cheese, 181
Curing, definition, 289
    losses of weight in, 304, 309, 310
    moisture losses in, 306
    precautions to observe, 299
    shrinkage, 305
    temperature and shrinkage, 307
    Water's patent, 296

Curing cheese, *see* Ripening
Curing cheese for processing, 358
Curing Coon cheese, 296, 298
Curing room, humidity, 197
  mold control, 198
  practices, 197
  shelves, 198
  temperature, 197
Curing treatments, 291
Current cheese for processing, 363
Cutting curd, 147
Cutting Cheddar cheese curd, 165
Cutting, size of knives, 167

Dahlberg (Geneva) Cream spread manufacture, 421
Dairy Industries Supplies Association, Inc. 271
Daisies, size of, 190
Defective cheese, markets for, 219
Defects in body of Cheddar cheese, 240
Defects in color of Cheddar cheese, 254
Defects in Cottage cheese, 402
Defects in finish of Cheddar cheese, 258
Defects in flavor of Cheddar cheese, 228
Defects in texture of Cheddar cheese, 243
Desiccator, 463
Diacetyl, 119, 323
Dipping, 149
  Baker's cheese curd, 425
  Cheddar cheese curd, 175
  Cottage cheese curd, 393
  Cream cheese curd, 414
Dirty finish, 260
Drainage for cheese factory, 446
Drainage bags, care of, 429
Drawing whey, 149
Dressing, 191
Dressing hoops, 195, 196
Dressing squares, 196
Dried whey production, U.S., 432
Drought, effect on milk composition, 28
Dry body, Cheddar cheese, 241
Dry-hand milking, 101
Drying curd by stirring, 177
Drying lamps for cheese test, 466
Dry skim milk, use in Cottage cheese, 400, 401
  standardizing with, 52

Elasticity of body, 239
Emulsifiers for process cheese, 356
Emulsifiers for processing, 366
  action of, 367
  adding, 369
  amounts, 369
Emulsifiers for processing (*cont'd*)
  choosing, 367
  composition of, 367
  purpose of, 366
  sandiness from, 367
Energy in cheese, 404
Environment of bacteria in cheese making, 81
Enzyme, lipases, 14, 140, 322
  pepsin, 142
  rennin, 7, 142
Enzymes and cheese, 140
Enzymes in milk, 14, 140
  pasteurization effect, 15
  phosphatase, 16
Epidemics from cheese, 91, 92
*Escherichia-Aerobacter*, 87, 88
  gassy texture cause, 244
Essentials of cheese making, 138
Extraneous matter standards, 468
Extraneous matter test, 468
  interpretation, 471
  phosphoric acid method, 472, 473
  precautions, 471
  size of cheese sample, 469
  sodium citrate method, 470

Factory, *see* Cheese factory
Factory statement, model, 77
Factory statements, 76
Fast-cured Cheddar cheese, 298
Fast-freezing Cheddar cheese, 302, 350
Fat, changes in ripening, 322
  effect on quality, 38
  losses in ripening, 304
  yield relation, 62
Fat globules, size of, 4
Fat-in-dry-matter, 32
  calculating, 40
  Cheddar cheese, 32
  relation to milk fat, 33
  table of, 42
Fat in cheese, test for, 461
Fat in milk, Babcock test for, 456
  calculating yield from, 65
  effect of feed on, 27
  effect of lactation, 21
  seasonal effect, 23
Fat in skim milk, test for, 460
Fat in whey, test for, 460
Fat-plus-0.6, 70
Fat-plus-casein, 71
  units in milk, 72
  units of, 72
Fat test for cheese, 461
Fat, *see* Cheese fat, Milk fat
Fatty acids, 3, 150, 322

Feed, effect on milk composition, 25, 27
  milk quality, 99
  strong flavored, 99
Feed flavor, Cheddar cheese, 231
Feed of cows, effect on milk composition, 27
Fermentation test, 111
  cheese quality, 112
  interpretation, 112
  modified, 112
  procedure, 111, 112
  significance, 112
Fermented flavor Cheddar cheese, 231
Filtration of milk, 155
Finish of cheese, 197
Finish, defects, bloated, 260
    checked rind, 258
    cracked rind, 258
    dirty, 260
    greasy, 260
    huffed, 260
    ideal, 286
    loose paraffin, 261
    lopsided, 263
    moldy, 261
    rind rot, 262
    scaly paraffin, 261
    trier marks, 262
  definitions of, checks, 286
    cracks, 286
    dirty, 286
    greasy, 286
    high edges, 287
    huffed, 287
    loose paraffin, 287
    lopsided, 287
    moldy, 287
    rind rot, 287
    rot spots, 287
    rough, 287
    scaly paraffin, 287
    smooth, 287
    soft spots, 287
    soiled, 287
    uneven, 287
    wrinkled bandage, 287
Firmness of body, 239
Flake-type Cottage cheese, 382
Flavor, absorption by milk, 99
  bacterial effect on, 86
  defective, acid, 228
    bitter, 228
    cowy, 230
    feed, 231
    fermented, 231
    fruity, 232
Flavor, defective *(cont'd)*
    moldy, 233
    rancid, 233
    unclean, 235
    weedy, 236
    yeasty, 237
  definitions of, acid, acidy, 281
    aged, 281
    barny, 281
    bitter, 281
    clean, 281
    cooked, 281
    cowy, 281
    feed, 281
    fermented, 281
    fishy, 281
    flat, 281
    foreign, 282
    fresh, 282
    frosted feed, 282
    fruity, 282
    gassy, 282
    heated, 282
    high, 282
    high-acid, 282
    highly pleasing, 282
    hydrogen sulfide, 282
    lacking, 282
    low, 282
    metallic, 282
    mild, 282
    moldy, 282
    nutty, 282
    offensive, 282
    off, 282
    onion, 282
    oxidized, 282
    putrid, 282
    quick, 282
    rancid, 282
    sharp, 282
    smothered, 282
    sour, 283
    stable, 283
    tainted, 283
    tallowy, 283
    unclean, 283
    utensil, 283
    weedy, 283
    whey taints, 283
    yeasty, 283
  fat effect, 5
  ideal, 281
  moisture effect on, 2
  ripened Cheddar cheese, 319
  temperature effect, 294, 295, 296

Flavor of Cheddar cheese volatile acids, 323
Flavor of milk, aeration, 101
  removal of off odors, 101
  vacreator effect, 101
Flexible wrappers for Cheddar cheese, 345
Flexible wrappers, merchandising, 349
Food and Drug Administration, Cottage cheese regulations, 385
  Cream cheese definition, 406
  definitions, 406
  gums for Cream cheese, 418
  Neufchatel cheese definition, 406
Food, Drug and Cosmetic Act, 94
Food value of cheese, 401
Forced-cured Cheddar cheese, 298
Formula for cutting time, 165
Formula for solids-not-fat, 496
Formula for total solids, 497
Freezing cheese, 300, 428
Freezing Cheddar cheese, 301, 302
Freezing points of Cheddar cheese, 300
Freezing points of Cottage cheese, 300
Fresh Cheddar cheese, 289
Froker-Hardin formulas, 74, 75
Frozen cheese, Cottage cheese, 400
Fruity flavor Cheddar cheese, 232
Functions, casein in cheese, 8
  fat in cheese, 5
  lactose in cheese, 9
  salts in cheese, 11
  water in cheese, 2

Galactase in cheese ripening, 14
Gas formers in Cheddar cheese, 89
Gases in cheese, 325
Gas-forming bacteria in Cheddar cheese, 89
Gassy texture, Cheddar cheese, 243
Gate pail, 174
Gate strainer, 174
Geneva Cream spread, 379, 421
  acid flavor, 421
  cheese flavor, 422
  food flavors, 422
  manufacture of, 421
Goodyear Tire and Rubber Company, 346
Grade and composition of Cheddar cheese, 36
Grades, tentative, United States Department of Agriculture, general specifications, 268
Grades, Wisconsin, 267
Grading cheese, 266
Granular-curd Cheddar cheese manufacturing process, 211
Granular-curd process, 209
Greasy curd, effect of, 184
Greasy finish, 260
Green cheese, 289
Grinders, for processing, 366
Guernsey milk composition, 21, 22
Gums for Cream cheese, 418
Gums for process cheese foods and spreads, 376

Heating, acid influence, 173
  fat influence, 172
  regulating Cheddar cheese, 172
Heating to check acid, 173
Hemolytic streptococci in cheese, 91
Hillside Cheddar cheese, 263
Holstein milk composition, 21, 22
Homogenization for cheese making, 141
Homogenized Cottage cheese, 423
Homogenizing, Cream cheese mix, 411
  cheese foods, 379
  cheese spreads, 379
  Geneva cream spread, 379
Hoop dressing, 191
Hooping curd, 189
Hooping temperature, Cheddar cheese, 191
Hot iron test, 175, 475
Hot-pack Cream cheese, 418. *See* Cream cheese
Huffed cheese, 260
Humidity, air in cheese boxes, 307
  curing effect, 306
Hydrogen ion concentration, 476. *See* pH
Hydrogen sulfide flavor, 282

Ideal color, Cheddar cheese, 286
Ideal starter, 132
Ideal texture, Cheddar cheese, 243, 285
Identity, casein, 6
  lactose, 9
  milk salts, 11
  milk sugar, 9
Identifying milk quality by testing, 114
Increase in acidity after coagulation, 146
Incubation of starter, 125
Incubators for starter, 121, 122
Individual cows, effect on milk composition, 21
  effect on milk fat, 22
Industrial uses of whey, 443
Infected udders, milk quality, 98
Inferior milk for cheese, 157
Inoculating starter, 125

Inspection of milk for cheese, 155
Insufficient acidity, 226
Interpretation, extraneous matter test on cheese, 471
  fermentation test, 111
  methylene blue test, 106
  microscopic examination of milk, 114
  milk sediment test, 106
  phosphatase test on cheese, 491
  phosphatase test on milk, 493
  resazurin test, 111
  Wisconsin curd test, 113
Interval of milking, effect on milk composition, 25
Iron in cheese, 404

Jersey milk composition, 21, 22
Judging cheese, 266
Judging Cheddar cheese, appearance terms, 286
  body terms, 283
  color terms, 286
  flavor terms, 281
  finish terms, 286
  procedure, 276
  techniques, 274
  terms used, 280
  texture terms, 285
Judging, distractions, 276
  examining plug, 277
  light, 274
  odor detection, 278
  odors, 275
  sampling, 276
  sanitary facilities, 275
  smelling, 278
  space, 274
  tasting, 279
  techniques, 274
  temperature, 275
  terms, 280
    aged, 281
    fresh, 280
    mild, 281
  trier, use of, 276

Kettles for processing, horizontal, 368
  steam jacketed, 368

Lactalbumin, 8
Lactate, calcium, in white specks, 324
  production in milk souring, 321
Lactation, effect on albumin, 24
  effect on casein, 24
  effect on fat, 22, 23, 24
Lactic acid, 321
  effects in cheese making, 9, 117
Lactic acid from whey, 441, 443
Lactic starter, 117. *See* Starter
Lactobacilli in Cheddar cheese, 86
*Lactobacillus brevis* var. *rudensis* in Cheddar cheese, 89
*Lactobacillus bulgaricus* gas production with *S. lactis,* 342
*Lactobacillus casei,* 86
*Lactobacillus helveticus,* 84, 118
*Lactobacillus plantarum* var. *rudensis* in Cheddar cheese, 89
Lactoglobulin, 8
Lactometer, Quevenne, 495
  use of, 496
Lactose, 9
  acetic acid from, 323
  changes in ripening, 322
  diacetyl from, 323
  disappearance in cheese, 323
  fermentation, by yeasts in Cheddar cheese, 88
    effect on flavor, 323
  identity, 9
  lactic acid from, 9, 441
  propionic acid from, 323
  residual, 10
  utilization, 10, 441, 443
  volatile acids from, 322, 323
Lactose in milk, functions, 9
Lap fold for packaging, 347
Laws, Food, Drug, and Cosmetic Act, 91
  state, 95
*Leuconostoc citrovorum,* 84, 118
*Leuconostoc dextranicum,* 84, 118
Legal composition, Cheddar cheese, 31
Legal standards, Cheddar cheese, 31, 40
  milk composition, 41
Lipase in milk, 14
Lipase in cheese, 322
Lipolysis of fat in Cheddar cheese, 322
Loaf cheese, *see* Process cheese
Location of cheese factory, 445
Longhorn cheese size, 190
Lopsided Cheddar cheese, 263
Loss of casein in whey, 57, 58, 59
Loss of fat in whey, 58, 59
Loss of milk solids in whey, 57
Loss of moisture in ripening, *see* Ripening
Losses of weight in ripening Cheddar cheese, 301
Losses of weight in ripening, *see* Ripening
Low-acid Cottage cheese, 382

Magnesium phosphate, 11
Marathon Corporation, 345

Manufacturing records, 153, 154
Marschall rennet test, 142
Marking Cheddar cheese, 199
  pasteurized milk, 208
Mastitis, Cheddar cheese, 98
  control, 98
  effect on milk composition, 26
  leucocytes, 97
  milk quality, 97
  slow acid development, 97
  yield of Cheddar cheese, 98
Matting curd, 178, 179, 180, 181
Mealy body, Cheddar cheese, 241
Mechanical agitation, 171
Mechanical openness, 248
Medium aged cheese for processing, 363
Menasha Products Company, 345
Method of cutting Cheddar cheese, 168, 169
Methylene blue test, 106
  apparatus, 108
  color change, 107
  cream layer, 107
  function, 106
  methylene blue solution, 108
  mixing, 107
  precautions, 110
  procedure, 109
  reduction time, 107
  relation to cheese quality, 96
  sampling for, 109
  significance for cheese, 108
  standards for cheese, 110
Microorganisms, cheese making, 79
  desirable in cheese, 83
  effect of environment, 80
Microscope, counting bacteria, 114
  identifying milk quality, 114
Microscopic count, 114
Milk, absorption of flavors, 99, 102, 103
  acidity, 159, 206
    development of, in ripening, 158
    testing for, 473
  adding color to, 162
  adding rennet to, 162
  adulterated, 94
  aeration, 104
  analysis, lactometer use, 495
  ash content, 11, 23, 24
  Babcock test for fat, 457
  bacterial sources, 84, 87
  cans, source of gas, 245
  care of, 79, 97
  casein, 6
  casein/fat ratio in, 33
  chemical composition for cheese, 56, 138
Milk (*cont'd*)
  clean, production of, 97
  coagulation defects, 144
  constituents, 1, 2
  definition, 1, 94
  fat-like substances in, 5
  gassy, 245
  inspection for Cheddar cheese, 155
Milk coagulation, acid, 143
  heat and acid, 144
  rennin, 142, 143. *See* Curd formation and Casein coagulation
Milk composition, average, 19
  breed effect, 20, 21, 22
  carbohydrates, effect of feed on, 27
  drought effect, 28
  factors affecting, 20
  fat, effect of feed on, 27
  feed effect, 25, 27
  fraction of milking effect, 26
  health of animal, 26
  individual effect, 21
  interval of milking, 25
  lactation effect, 22
  legal Cheddar cheese, for, 41
  mastitis effect, 26
  minerals, effect of feed on, 27
  pasture, effect of, 28
  protein, effect of feed on, 27
  season effect, 23, 24
  temperature effect, 25
  vitamin, effect of feed on, 28
Milk constituents, in cheese, 57
  in whey, 57
  proportions, 19
  variations, 19
Milk cooling, equipment, 102
Milk enzymes, 14
  functions of, 14
Milkers, 101
Milk fat, 3
  composition, 3
  density, 5
  fatty acids in, 3
  functions in cheese, 5
  globules, size, 4
  individual variations, 22
  losses in whey, 58
  melting point, 4
  normal milk in New Zealand, 29
  paying for milk, 69
  physical state, 4
  recovery in Cheddar cheese, 60
  relation to casein, 28
  relation to fat in cheese, 33
  relation to solids, 20
  relation to yield, 61

Milk fat (*cont'd*)
  specific heat, 4
  test for, 456
Milk flavor, 103
Milk gases, 16
  significance, 17
Milk house, 102
Milking, 98
  dry-hand, 101
  machines, care of, 100
  methods, 100, 101
  parlor, 102
  technique, 98, 100
  utensils, care of, 99
    clean procedures, 99
Milk, normal, 1, 94
Milk odor, 103
Milk, paying for, 68
Milk pigments, 12
Milk production of high quality, 97
Milk properties for cheese, 138
Milk proteins, 6
  function, 8
  season effect, 24
Milk quality, aeration, 104
  acceptable, 95
  cheese making, 94
  clean cows, 98
  clean udders, 98
  cooling for, 102
  cow barn odors, 99
  cow barns, 99
  effect of strainer, 102
  effect on cheese, 96
  feed, 99
  flavor and odor, 103
  healthy cows, 97
  infected udders, 98
  leucocytes, 97
  milking machines, 98
  milking technique, 98, 99
  odor, 103
  protecting, 102
  tests for, 103
Milk quality and cheese making, 94
Milk quality standards, 94
  Food, Drug and Cosmetic Act, 94
  United States Public Health, 94
Milk quality test, acid test, 113
  fermentation, 111
  flavor and odor, 103
  methylene blue, 106
  microscopic, 114
  nose test, 103
  plate counts, 114
  resazurin, 110
Milk quality test (*cont'd*)
  sediment, 104
  Wisconsin curd test, 113
Milk salts, 11, 323
  function, 11
  identity, 11
  significance, 11
Milk sediment, sources of, 105
Milk sediment test, 105
  dipper strainer, 106
  interpretation, 106
  procedure, 106
Milk solids distribution in making Cheddar cheese, 57, 58
Milk solids, recovery in Cheddar cheese, 60
Milk straining, 101
Milk sugar, 9
  functions, 9
  identity, 9
Milk trucks, 102
Milk units of fat-plus-casein, 72
Milk utensils, sterilization, 100
Milk vitamins, 13
  function of, 13
Milk, water in, 1
    functions in cheese, 2
Milk yield, interval of milking, 26
Milling Cheddar cheese, acidity, 182
  losses, 184
  method, 182
  purpose of, 182
Minerals in cheese, 404
Modifications of Cheddar cheese, 202
Moisture/casein ratio, 63
Moisture, Cheddar cheese, 31, 32, 36
  control, 180
  Cottage cheese, 399
  Cream cheese, 406, 409
  defects, 219
  effect on appearance, 3
  excessive, causes, 220
    defects, 219
    preventions, 220
    remedies, 220
  functions in cheese, 2
  lack of, causes, 222
    effects, 221
    preventions, 222
    remedies, 222
  losses in ripening, 306
  Neufchatel cheese, 406
  process cheese, 356
  quick test for cheese, 465
  ratio to solids-not-fat, 38
  relation to quality, 38

Moisture *(cont'd)*
  relation to yield, 62, 64
  yield table, 67
Moisture test, desiccator, 463
  dishes, 463
  drying lamp, 465
  equipment, 462
  method, 462
  oil test, 465
  ovens, 463
  procedure, 464
  short, quick, 465
Moisture, yield, 62, 64
Mold defect, Cheddar cheese, 89
Mold growth on packages, 349
Moldy cheese, 261
Moldy flavor, Cheddar cheese, 233
Mono-calcium paracaseinate, 321, 327, 328
Monrad rennet test, 142
Mottled color, 255
Munsell Color Company, 111
Mysost, 437

National Cheese Institute, Inc., 452
  address, 105
  extraneous matter standards, 468
  Milk Code, 95, 155
Neufchatel cheese, 406
  bacteria, undesirable in, 87
  definitions, 406
  fat content, 406
  ingredients, 407
  making traditional type, 426
  moisture content, 406
  preservation, 428
  traditional type, 426, 427
  starter, 81
Neutralizing acidity, 139
Nose test for milk quality, 103
Niacin in cheese, 404
Nitrogen, changes in ripening, 321, 327, 328, 329, 330, 332, 333
Nitrogen in milk, 16
Nutritive value of cheese, 404
Nutty flavor, 282

Odor absorption by milk, 99
Off flavor, 282
Offensive flavor, 282
Onion flavor, 282
Openings, mechanical, 248
Openness, clarification of milk, 250
  effect of salt, 252
  mechanical, carbon dioxide, 249
    Cheddar cheese, 248
    starters, 250
Openness, mechanical *(cont'd)*
    storage temperature, 253
  slit, *Lactobacillus brevis,* 250
    *Streptobacterium plantarum,* 250
Open texture, 243, 285
Ovens, drying, for cheese, 463
Oxidized flavor, 282
Oxygen in milk, 16

Packaging cheese, 335
  canned, 341
  canning methods, 343
  canning precautions, 344
  Cheddar cheese, 335
  cheese requirements, 336
  Club cheese, 352
  comminuted cheese, 352
  conditions of, 337
  consumer requirements, 338
  consumer units, 348
  fast-freezing, 350
  flexible wrapper method, 346
  flexible wrappers, 345
  general considerations, 335
  ground cheese, 352
  methods of, 339
  miscellaneous methods, 350
  mold growth, 349
  Parakote, 346
  Pliofilm, 346
  store packaging, 351
  utilizing edible scraps, 356
  vacuum canning, 342
  valve-vented cans, 342
  waxed-cured cheese, 340
  waxed prints, 339
  waxed slices, 340
  wrapped-waxed cheese, 341
Packaging hot-pack Cream cheese, 419
Pails, small tops, 101
Pale color, 254
Paracasein, 7
  soluble calcium salts effect, 7, 142, 321
  action of acid on, 8, 321
Paraffin, kinds, 198
  loose, 261
  overheating, 200
Paraffining, 198
Paraffining Cheddar cheese, age and shrinkage, 312
  duration of dip, 200
  effect on shrinkage, 309, 310, 311
  preparation, 199
  purpose, 198
  temperatures, 199
Parafilm, 345
Parakote, 345

Pasteur-Chamberland filter, 6
Pasteurization, bacterial control by, 82
  definition, 156
  effect on calcium, 321
  effect on phosphorus, 321
  for Baker's cheese, 407, 424
  for Cheddar cheese, 1, 56, 202
  for Cottage cheese, 385
  for Cream cheese, 407, 410
  for Neufchatel cheese, 407, 426
  high temperature, 156, 157
  holder method, 157
  inferior milk for cheese, 157
  quality of milk and cheese, 157
  quality of milk for, 157
  test for, 486
  temperatures of, 156, 157
Pasteurization and epidemics from cheese, 92
Pasteurized milk, making into Cheddar cheese, 156, 202
Pasteurized-milk Cheddar cheese, curing, 208
  making schedule, 204
  marking, 208
  shrinkage before paraffining, 308
Pasteurized milk for Cottage cheese, 385
Pasteurized milk, regularity of making cheese with, 158
Pasteurized-process cheese, 356
Pasteurizing Cream cheese mix, 410
Pasteurizing milk for Cheddar cheese, 205
Pasture, effect on milk composition, 24, 25
Pasty body, Cheddar cheese, 212, 284
Patents, process cheese, 357
Pathogenic organisms, epidemics, 91
  survival in cheese, 91
Pathogenic organisms and cheese, 90
Paying for milk for cheese, 68
Paying for milk, methods compared, 75, 76
  fat-plus-0.6, 70
  fat-plus-casein, 71
  fat method, 69
  Froker-Hardin method, 73
  methods, 68
  weight method, 69
Pearson's Square, 46
Pepsin, 142
Peptones, 320, 327, 328
Percentage yield, 62
Perfect, body, 271, 283
  color, 271, 286
  finish, 271, 286
Perfect (*cont'd*)
  flavor, 271, 281
  texture, 271, 285
Personnel, health and cleanliness, 453
pH at dipping Cheddar cheese, 175
pH apparatus, 478
pH tables for converting voltage, 481
pH test for acidity, 476
pH test for cheese, 479
pH test for liquids, 477
pH test, precautions, 480
Phage, 89. *See* Bacteriophage
Phosphatase test, 486
  Cheddar cheese, 487
  field tests, 493
  interpretation for cheese, 491
  laboratory test, cheese, 489
  laboratory test, milk, 492
  precautions, 491
  process cheese, 356
  rapid field test, cheese, 491
  rapid field test, milk, 493
Phospholipides, 5
Phosphoprotein, 6
Phosphorus in Cheddar cheese, 324
Phosphorus in cheese, 324, 404
Physical properties of milk, control of, 141
Pigments, changes in ripening, 325
  functions of, 12
Pinholes, 243, 285
Plasticity of body, 239
Plate count, examination of milk, 114
  limitation, 114
Pliofilm, 346
Pot cheese, 382
Potassium phosphate, 11
Press cloths, 192
  salting, 346
  sticking, 346
  substitutes, 192
  wicking effect, 192
Press for cheese, 195
Pressing cheese, 150
Primost, 437
Procedures of cheese making, 138
Process cheese, 355
  acids added, 356
  age of blend, 360
  analysis, 358
  batch, 364
  blending, 359, 362
  body for blend, 362
  boxes for, 374
  cleaning cheese, 361
  cleaning, method of, 364
  cleaning, time of, 361

Process cheese (*cont'd*)
  cold-cured cheese for, 359
  color, addition of, 369
  composition for blend, 362
  cookers for, 368
  cookers, location of, 366
  cooling, 373
  curing cheese for, 358
  definition, 355, 356
  emulsifiers, 356, 366
  emulsifiers, adding, 369
    amount of, 369
    choosing, 367
    effect on body, 366
  fat separation, 373
  flavors for blend, 361
  flexible wrappers, 365
  grading for, 358
  grinders, location of, 366
  grinding, 365
  grinding, special equipment, 366
  heating, 371
  heating changes, 372
  heating duration, 372
  kettles for, 368
  kettles, vacuum-pressure, 368
  labeling, 357
  melting properties with Rochelle salts, 367
  mill, 366
  moisture content, 356
  packages for, 374
  packaging, 373
  patents, 357
  phosphatase test, 356
  pouches for, 374
  procedure for making, 369
  procurement of cheese, 357
  quartering, 365
  salvaging scrapings, 365
  shelf-cured cheese, 358
  size of blend, 361
  standardizing moisture, 370
  standards, 356
  sweet cream in, 356
  tempering for cleaning, 364
  texture for blend, 361
  trimming losses, 365
  trimming losses, flexible wrappers, 365
  use of trimmings, 365
  water, addition of, 369
  water, calculating amount, 370
  water from condensate, 370
  wrappers for, 374
Process cheese foods, 375
  acidity control, 378
  blending for, 376
Process cheese foods (*cont'd*)
  fat adjustments, 377
  heating temperatures, 379
  homogenizing, 379
  lactose limits, 378
  manufacturing, 376
  moisture adjustments, 377
  packaging, 379
  skim milk concentrates, 377
  standards for, 375
  whey concentrates, 377
Process cheese spreads, 375
  acidity control, 378
  blending for, 376
  fat adjustments, 377
  heating temperatures, 379
  homogenizing, 379
  lactose limits, 378
  manufacturing, 376
  moisture adjustments, 377
  packaging, 379
  skim milk concentrates, 377
  standards for, 375, 376
  whey concentrates, 377
Processed cheese, consumer preferences, 290
Proteins, changes in ripening, 320
  cheese, 404
Proteins, flavor, 322
  loss in whey, 59
  milk, 5
  recovery in Cheddar cheese, 60
  salt-soluble, 320
  solubility in ripening, 321
  time for changes in ripening, 327
  water-soluble, 327, 328
*Pseudomonas fluorescens* in Cheddar cheese, 89

Quality milk standards, 94
Quality of cheese, 31
  milk quality and, 94
  pasteurized, 157
  relation to fat, 38
  relation to methylene blue test, 96, 97
  relation to moisture, 38
  temperature effect, 294, 295, 296
Quality of milk, tests for, 103
Quevenne lactometer, 496
Quinhydrone electrode, 477

Rancid flavor, Cheddar cheese, 233
Raw-milk cheese, shrinkage before paraffining, 308
Receiving milk, 155
Records for Cheddar cheese, 153, 154
Red spots in cheese, 89, 256

Removal of whey from curd, 147
Rennet, adding to milk, 163
  action in ripening, 320, 332
  alkali effect, 162
Rennet, Baker's cheese requirements, 421
  Cheddar cheese requirements, 162
  Cottage cheese requirements, 387
  Cream cheese, use, 412
  defects in coagulation by, 144
  Neufchatel cheese requirements, 412, 427
  temperature of milk, 162
  variations in amounts, 163
Rennet coagulation, 7, 142
Rennet extract, 7, 142
Rennet test, 142, 498
Rennin in rennet extract, 7, 142
Resazurin test, 110
  color changes, 110, 111
  interpretation, 111
  procedure, 110
  tablets, 110
Riboflavin in cheese, 326, 404
Riboflavin in milk, 12
Ricotta, 437
Rind, cracked, 258, 286
Rind rot, 261, 262
Ripening agents, Cheddar cheese, 318
Ripening cheese, 150
  art of, 151
  biological agents, 151
  biological measurements, 326
  changes in, 150, 289, 318
  chemical changes, 151, 319
  chemical measurements, 326
  cold-curing, 291
  definition, 289
  detecting, 151
  environment, 151
  factors affecting, 327
  fat in, 322
  finish for, 299
  judging, 326
  lactose in, 322
  losses, 306
  losses of carbon dioxide, 305
  losses of fat, 304
  losses of moisture, 306
  losses of weight, 301
  losses, temperature effect, 307
  low temperature, 291
  measuring, 151, 326
  milk salts in, 323
  moisture, 320, 330
  pasteurized milk effect, 333
  physical measurements, 326
Ripening cheese (*cont'd*)
  physical changes, 151, 319
  protein changes, 320, 326
  rate, 152
  rennet effect, 332
  riboflavin, 326
  salt effect, 332
  selecting cheese, 299
  size of cheese, effect, 330
  supervision, 299
  technology, 289
  temperature effect, 292, 328, 329
  time effect, 327
  tyrosine in, 325
  vitamins in, 325
  warm-curing, 294, 297
  water-soluble nitrogen, 326
Ripeness in milk, rennet test for, 497
Ripening milk for setting, 158
Ripening milk, schedule for Cheddar cheese, 159
Rule for calculating milk casein, 29
Rule for calculating time for cutting, 165
Running the whey, 149
Rusty spots, 89, 256

Salt, effect on gas bacteria, 247
  effect of variation on Cheddar cheese, 188
  effects on ripening, 331
  how to apply, 188
  kind for, cheese, 188
  purpose of adding, 186
  time of adding to Cheddar cheese, 184, 186
Salting, 150, 186
  Baker's cheese, 426
  Cheddar cheese, 187
  Cottage cheese, 395, 399
  Cream cheese, 417, 419
  Neufchatel cheese, 428
Salt test for cheese, 467
Sampling cheese, extraneous matter test, 469
  for analysis, 461
  plug sample, 461
  V-shaped sample, 469
  wedge sample, 461
Sanders and Sager phosphatase test, 487, 492
Sandiness in process cheese, 367, 377
Sandy body, Cheddar cheese, 242
Sanitation, control in factory, 454
  cow barns, 99
  efficiency relation, 454
  factory, 454

Sanitation (*cont'd*)
  factory personnel, 453
  factory requirements, 450, 452
  factory surroundings, 449
  Federal Food and Drug Administration regulations, 454
  interpretation of extraneous matter test on cheese, 471
  interpretation of microsopic examination of milk, 114
  interpretation of sediment test on milk, 104
  milking technique, 99
  milk production, 97
  milk standards, 94
  milk utensils, 99
  plant layout, 450
  preparation of equipment for use, 153
  protected zones in plants, 450
  protecting milk, 102
  reasons for, 454
  reputation of business, 454
  responsibility for, 455
  significance of milk flavors, 103
  utilization of whey, 443
Scalding, 148
Scale boards, 200
Schedule of making Cheddar cheese, 204
Score card for Cheddar cheese, 271
Scores of Cheddar cheese, normal range, 271
Scoring Cheddar cheese, body, 272
  color, 273
  finish, 273
  flavor, 272
  texture, 272
Scoring cheese, 266, 271
Seamy color, 257, 273, 286
Season, effect on milk composition, 24
Seed starter, 119
Sediment, sources in milk, 105
Sediment test for cheese, 468. *See* Extraneous matter test
Sediment test for milk, 104
  apparatus, 105
  curd in, 106
  dipper strainer, 106
  interpretation, 106
  procedure, 106
  results, 105
  sampling for, 105
Septic sore throat, 91
Shape of cheese, shrinkage, effect on, 309
Shelf cured Cheddar cheese, 298
Shelf-curing Cheddar cheese, 296
Shipment, boxing cheese for, 200
Short body, Cheddar cheese, 242
Shrinkage, age at paraffining, 314
  Cheddar cheese, 315, 316
    effect of shape, 309
    effect of size, 309
    in ripening, 305
    in storage, 312
    pasteurized-milk cheese, 308
    raw-milk cheese, 308
  duration of storage, 312
  humidity effect, 306
  in curing, 305
    causes of, 304
  moisture in cheese, 315
  moisture losses, 306
  non-paraffined cheese, 309, 310
  paraffin effect, 308, 310, 312
  paraffin type, 314
  Parafilm effect, 314
  pasteurized-milk cheese, 314
  storage temperature effect, 308
  style of Cheddar cheese, 309
  temperature effect, 307, 312, 315
  texture effect, 316
  time of paraffining, effect, 312
Skim milk, fat test, 460
  standardizing with, 44
  standardizing with dry skim milk, 52
Slit openness, 250
Slow acid development, mastitis, 97
Smoke flavor, 352
Smoking in cheese factory, 454
Soaked-curd process, 213
Sodium benzoate, 142
Sodium chloride in rennet extract, 142
Sodium citrate, 11, 356
  test, cheese sediment, 470
Sodium metaphosphate, 356
Sodium metasilicate for draining bags, 429
Sodium phosphates, 356
Sodium pyrophosphate, acid, 356
Sodium tartrate, 356
Soft unripened cheese, making, 382, 406
  preservation, 428
Solids, cheese-solids, 61
Solids-not-fat, estimating, 496
  ratio to fat in standardizing, 52
  ratio to moisture in cheese, 51
Solids, total, estimating, 496
Solvents for cheese sediment test, 469
Specific heat of cheese, 371
Specific gravity of milk, 21, 24
  measuring, 495
Specks, white, in Cheddar cheese, 257, 324

Spore-forming bacteria in Cheddar cheese, 89
Square prints, 190, 346
Stabilizers for Cream cheese, 418
Stabilizers for pasteurized-process cheese spreads, 376
Stages of cheese making, 138
Standardization, accuracy of control, 48
  adjustments, 41
  casein measurements for, 43
  checking results, 51
  composition of milk, 41
  cream from, 53
  cream removal, 44
  dry skim milk for, 52
  fat measurements, 43
  fat required in standardized milk, 46
  formula for, 45
  methods, 44, 45, 46, 47
  milk to separate, 48
  Pearson's Square, 46
  quality effect, 53
  skim milk used for, 44
  variations, 49
  variations in results, 47
  variations, reasons for, 50
  weight of milk, 41
  yield, 53
Standardizing milk for cheese, 40, 139
Standards, industrial, for milk, 95
  legal, Cheddar cheese, 31, 40
    Cottage cheese, 399
    Cream cheese, 406
    Neufchatel cheese, 406
    process cheese, 356
  milk quality, 94
Starter, 117
  acetylmethylcarbinol, 119
  acid control with, 160
  acidity, 127, 132
  acid-producing, 117
  adding to milk, 161
  activity, 128, 132
  activity test, 498
  aroma and cheese flavor, 119
  aroma from citric acid, 119
  aroma producers in, 118
  associated organisms, 118
  bacteria in, 84
  bacterial control by, 82
  bacteriophage, 132
  Baker's cheese, 84, 424
  body of, 132
  building for, 120
  Cheddar cheese, 85, 158, 160, 161
  cheese starter, 119
  chilling, 126
Starter (*cont'd*)
  container covers, 121
  containers, 121, 122
  cooling after ripening, 126
  cooling milk for, 124
  coolers, 121, 122
  Cottage cheese, 84, 386, 387, 398, 401
  Cream cheese, 84, 413
  diacetyl, 119
  dry skim milk for, 124
  effect of cooling, 126, 127
  equipment for cheese starter, 122
  equipment for seed starter, 121
  facilities, 121, 122
  factors affecting amount, 161
  flavor of, 119, 132
  functions of, 117
  ideal, 132
  gassy, 245
  heat-loving, 117
  heating milk for, 124
  how to add to milk in vat, 161
  inoculating, 125
  incubation, 125
  incubators, 121, 122
  kinds, 117
  laboratory, 120
  lactic, 117
    temperature of action, 117
    uses of, 117
  making cheese starter, 129
  making seed starter, 129
  milk for, 123
  milk protection, 124
  Neufchatel cheese, 84
  number to propagate, 120
  organisms in lactic, 118
  over-ripening, 128
  over-ripening and activity, 128
  over-ripening and flavor, 128
  pasteurized-milk cheese requirements, 158
  pipettes for, 121
  procedure for making, 129
  propagating, 119
  quality milk for, 123
  review, 119
  ripeness, 127
  room for, 120
  seed, 119
  selection of milk, 123
  scheme of carrying seed, 131
  skim milk for, 123
  source, 120
  steps in propagating, 129
  sterilizing milk for, 124
  tank for, 122

Starter (*cont'd*)
  temperature measurements, 125
  temperature of holding, 125
  time to add to Cheddar cheese, 160
  types in cheese making, 84
  vat, 122, 123
  water bath, 121
Statements, 76, 77
  model, 77
State of Illinois, Division Foods and Dairies, 468
Sterilizing, draining cloths for soft cheese, 429
  equipment, 153
  equipment for methylene blue tests, 110
  milk for starter, 124
  milk utensils, 100
  with chlorine, 100, 101, 134, 153, 429
Sticky body in Cheddar cheese, 242
Stirred-curd Cheddar cheese, characteristics, 210
  composition, 210
  curing, 212
  draining, 211
  history, 209
  hooping, 212
  manufacturing process, 211
  marking, 212
  mechanization, 209
  pasteurized milk for, 209
  quality, 210
  salting, 211, 212
  scoring, 210
  process, 209
Stirring Cottage cheese curd, 391
Storage, Cottage cheese, 399
  Cottage cheese in brine, 400
  short, for soft unripened cheese, 428
Storage temperature, Cottage cheese, 428
  Cream cheese, 428
  hot-pack Cream cheese, 428
  shrinkage, effect, 307
Store packaging of cheese, 351
*Streptococcus citrovorus,* 118
  volatile acids, 118, 119
*Streptococcus cremoris,* 84, 118
*Streptococcus lactis,* 84, 118
  Cheddar cheese, 85
  gas production with *Lactobacillus bulgaricus,* 342
*Streptococcus lactis* var. *anoxyphilus,* 118
*Streptococcus lactis* var. *hollandicus,* 118
*Streptococcus lactis* var. *tardus,* 118
*Streptococcus paracitrovorus,* in Cheddar cheese, 86, 118
  carbon dioxide production by, 118
*Streptococcus pyogenes,* 91
*Streptococcus thermophilus,* 84, 117
Sweet-curd Cottage cheese, 382
Sweetening agents for pasteurized- process cheese spreads, 376

Tables of pH and voltage, 481
Temperature, effect on milk composition, 25. *See* Cheese, Pasteurization, Ripening, Storage, etc.
Testing buttermilk, fat, 460
Testing cheese, acidity, pH, 476, 479
  extraneous matter, 468, 472
  extraneous matter supplies, 470
  fat, method, 461
  moisture, method, 462, 465, 466
  pH, 476, 479
  phosphatase, 486, 489
  salt, method, 467
  salt, reagents for, 467
Testing cream for fat, 459
Testing curd, acidity by hot iron, 475
  acidity, pH, 476, 479
Testing liquids, acidity, pH, 476, 477
  acidity, titratable, 473
Testing milk, acidity, pH, 476
  acidity titration, 473
  casein, 494
  composite sample, 456
  density, 495
  fat, 456
  lactometer, 495
  phosphatase, 492, 493
  quality, 103
  ripeness by rennet test, 497
  specific gravity, 495
Testing skim milk, fat, 460
Testing starter activity, 498
Testing whey, acidity, pH, 476, 477
  acidity, titration, 473
  fat, 460
Tests, acid, 473, 475, 476
  fat, 456, 460, 461
  moisture, 462, 465, 466
  pH, 476, 479
  phosphatase, 486, 489, 492, 493
  salt, 467
Texture, 243
Texture, defects, 243, 271, 272, 285
  definitions, candle, 285
    close, 285
    compact, 285
    crack, 285
    fish-eye, 285

- Texture, definitions *(cont'd)*
    - fissure, 285
    - gas holes, 285
    - loose, 285
    - mechanical openings, 285
    - open, 285
    - pinholes, 285
    - porous, 285
    - shot holes, 285
    - sweet holes, 285
    - swiss holes, 285
    - yeast holes, 285
  - judging, 271
  - moisture effect, 220
- Texture of Cheddar cheese, control, 180
  - gassy, 243
    - causes, 244
    - preventions, 244
    - remedies, 244
  - ideal, 243, 285
  - mechanical openness, 248
    - causes, 249
    - preventions, 250
    - remedies, 250
  - types of, 243
  - yeasty, 248
    - causes, 248
    - preventions, 248
    - remedies, 248
- Texture scoring, 271, 272
- Thiamine in cheese, 401
- Titratable acidity test, procedure, 474
  - theory, 474
- Total solids in milk, estimating, 496
- Trickling filter, 448
- Trier marks, 262
- Triple E Supplies, cheese sediment test, 470
- Turning cheese, 197, 262, 293, 298
- Twin style Cheddar cheese, 190
- Typhoid fever epidemics from cheese, 91
- Tyrosine in Cheddar cheese, 325

- Unclean flavor, 235
- Uncured Cheddar cheese, 289
- Undesirable bacteria in cheese, 88
- Undulant fever, 91
- Uneven color of rind, 263
- Uneven surfaces of rind, 263
- Uniformity of pasteurized-milk cheese, 157
- United States Department of Agriculture, Cheddar Cheese grades, 268
- United States Public Health Service, 91, 156
  - definition of milk, 91
- University of Wisconsin, 452
- Unsalted Cheddar cheese curd, 186
- Utensils for milking, care of, 99
- Utensils for milking, construction, 99

- Vacuum canning of cheese, 342
- Vacuumizing milk for cheese, 141
- Vacuum kettle for process cheese, 368
- Vacuum preservation, soft unripened cheese, 428
- Valve-vented cans for cheese, 342
- Vegetable gums, Cream cheese, 418
  - pasteurized-process cheese spreads, 376
- Vitamin A, 325, 404
- Vitamins, 28
  - in cheese, 401
  - in milk, 13
  - ripening, changes in, 325
- Volatile acids, 86, 321, 323, 326
  - starter, 118
  - *Streptococcus citrovorus*, 118, 119

- Walker casein test, 494
- Warm-cured Cheddar cheese, 294, 297
  - care of, 298
  - uses of, 298
- Warm-curing Cheddar cheese, duration, 298
  - humidity, 297
  - paraffining, 297
  - temperatures, 297
  - precautions in, 299
- Washed-curd Cheddar cheese, calcium salts removed, 215
  - composition, 213
  - lactose, effect of added, 214
  - manufacturing, 213
  - marking, 215
  - qualities, 213
  - ripening, 215
  - washing, duration, 214
  - washing, effects of, 214
- Washed-curd process, 213
- Washing curd at milling, 184
- Water, changes in ripening, 320
- Water's patent, curing method, 296
- Wax, 198
  - microcrystalline, 198
- Waxed prints of cheese, 339
- Waxed prints of cured cheese, 340
- Waxed slices of cured cheese, 340
- Weak body, Cheddar cheese, 242
- Weedy flavor, Cheddar cheese, 236
- Weight, changes in curing, 306
- Wetting agents for utensils, 100
- Whey acidity, after cutting curd, 170
  - schedule of, in making Cheddar cheese, 159, 201, 206

Whey, butter from, 437
  cheese, 437
  cheese products from, 437
  composition, 57, 58, 59, 431
  concentrate, acidity of, 439
    Beaumé, 438
    crystallizing, 438
    manufacturing, 438
    plain, 438
    seeding, 439
    sour, 442
    specific gravity, 438
    sweetened, 440
    uses, 439
Whey concentrates for processing, 377
Whey, dipping, 149
  disposal problem, 436
  draining, 149
  drawing, 149
  dried, for processing, 377
    manufacturing, 440
    production, 432
Whey fat, American Association test, 460
  test for, 460
Whey, fat utilization, 437
  fermentation industry, 443
  grass silage, use in, 442
  human food, 437
  industrial uses, 443
  methods of using, 435
  miscellaneous food uses, 441
  penicillin, 443
  processes of using, 434
  processing plants, size of, 435
  production, by months, 433
  production in U. S., 432
  products, 434
  protein losses from Cheddar cheese, 59
  removal from curd, 149
  removal of, 147
  running, 149
  salt in, for feed, 443
  sewage problem, 436
  stock feeding with, 442
  stream pollution with, 436
  surplus, disposal of, 436
Whey *(cont'd)*
  sweetened concentrate, 440
  tanks for hauling, 444
  tanks for storage, 444
  tanks, gas bacteria in, 245
  total solids, density relation, 438
  transportation, 443
  unwanted whey, 436
  utilization, 431, 434
  utilization, sanitation, 443
White specks in cheese, 257, 324
Wisconsin curd test, 113
  equipment for, 113
  interpretation, 113
  modification, 113
  procedure, 113
Wisconsin Cheese Makers Association, 452
Wisconsin Department of Agriculture, 452
  cheese grading regulations, 267
Wrapped-waxed packages, 311
Wrinkled bandage, 261

Yeasty flavor, Cheddar cheese, 237
Yeasty texture, Cheddar cheese, 248
Yield, Baker's cheese, 426
  calculating, 65
  casein/fat ratio effect, 62
  Cheddar cheese, 65, 67
  Cottage cheese, 395
  Cream cheese, 420
  estimating, 64
  factors affecting, 55
  factors for moisture, 66
  formula, 65
  Neufchatel cheese, 428
  normal, 61, 62
  percentage, 62
  per pound of fat, 62
  relation of fat and casein to, 61
  table, 67
Young American style, 190

Ziger, 437

17.7.81

9/8/09

25.4.97

CHECKED
2008

VERIFIED
2013

C. F. T. R. I. LIBRARY, MYSORE.

Acc. No. 1601 F8,3M ~~F85,3M~~ ~~N49~~
Call No. ~~Ek 31:8~~ ~~H9~~ N27;49

Please return this publication on or before the last DUE DATE stamped below to avoid incurring overdue charges.

| Due Date | Return Date | Due Date | Return Date | Due Date | Return Date |
|---|---|---|---|---|---|
| 8.9.67 | 6.9.67 | 4.12.76 | 3.12.76 | | |
| 9.11.67 | 9/11/67 | 18.12.76 | 17/12 | | |
| 24/11/67 | 13/11 | 1.1.77 | 1.1.77 | | |
| 18.12.70 | 17/12 | 16.1.77 | 13/1 | | |
| Ref. 212 | | 28/1/77 | 31.1.77 | | |
| | | 15.2.77 | 16/2 | | |
| 15-1-71 | 7.1.71 | 2.3.77 | 18/2 | | |
| 25.12.74 | 26/12 | | | | |
| 10/1/75 | 5/1 | 8.3.1979 | 12.3.79 | | |
| 17.9.75 | 11.9.75 | | | | |
| 27.5.76 | 12/5 | | | | |

CFTRI-MYSORE
1601
Cheese.

35,3M
~~EK 31: 8~~ Hq
ANSLYKE
ce"
9
✓
9